European Petroleum Industry Association

Recycle of Used Oils: Legal and Technical Considerations

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II. *Executive summary*

The EU directives which regulate used oils management encourage effective collection for pollution prevention, followed by re-refining (regeneration) into lubricant base oils as the most energy efficient disposal option. EUROPIA believes that conditions have changed since the original directive on Waste Oils and its amendment were enacted.

The current emphasis placed by the EC on regeneration of used oils over other responsible recovery options is misplaced. It does not result in energy or resource savings and it does not recognise the possible dual use of lubricant petroleum products both as a lubricant and as a fuel e. g. as a fuel replacement in cement kilns.

EUROPIA has reviewed the published information on Life Cycle Analysis (LCA) for the disposal of used oils. All data were analysed on the same basis taking into account the refining and marketing of the oil products as well as production and consumption of base oils in the EU.

The results show that combustion in cement kilns, or controlled combustion in power plants, is the best option in terms of crude oil consumption and carbon dioxide emissions. These results also indicate that maximising collection is the best policy to reduce either crude oil or energy consumption.

The analysis of the quality parameters and operational cost for production of virgin and re-refined base oils shows that re-refining of used oils to base oils with quality equivalent to virgin base oils requires severe hydrotreatment and thus high operational costs and energy consumption.

Regarding health and safety aspects of re-refined base oils, a good number of uncertainties over the potential health and environmental hazards of re-refined base oils still exist, suggesting the need for a case by case evaluation before their use in lubricants.

In the light of this, EUROPIA has adopted its position on the collection and disposal of used oils based on the following principles:

- EUROPIA welcomes and supports any initiative aimed at maximising the collection of used oils following the EU strategy for waste management

- EUROPIA supports any disposal option that ensures high levels of safety for the environment and public health.

- EUROPIA does not support the mandated or legally enforced priority of any specific disposal method.

- EUROPIA believes that all technically and environmentally acceptable disposal options should be treated in an equal manner. Any system of subsidies should avoid preferential treatment of any disposal method and should not distort the single market

- EUROPIA opposes any mandated requirement for the blending of regenerated base oils in the formulation of finished lubricants.

- EUROPIA supports that the same health and safety data be supplied with regenerated base oils as is required for virgin base oils.

1. *Introduction*

This report contains relevant technical information supporting the EUROPIA used oil position and should be seen a reference companion to the Position Paper.

Since used oils are classified in the EU legislation as hazardous wastes, all aspects regarding their recycling and/or disposal to the environment must be considered in the framework of the pertinent legislation. The essential aspects of the EU legal framework are summarized in Chapter 2.

Technical aspects regarding production and composition of used oils in the EU are included in chapter 3. This chapter also describes product quality requirements and performance characteristics of base oils. Energy consumption and material balances for production and for several disposal methods are included in chapter 4. This chapter also discusses economic, environmental and health aspects related to the disposal options analysed.

Regeneration of used oil to base oils is considered in the EU legislation as the preferential option for disposal. However this report concludes that other alternatives are at least equally efficient. The feasibility of disposal of used oils as fuel in cement kilns is analysed in chapter 5.

The information contained in these chapters is complemented by several annexes, which provide a more detailed description of the aspects discussed.

2. *Summary of legal framework*

2.1 Waste Oils Directive (75/439/EEC)

2.1.1 Summary

The principal EU legislation on the treatment of waste oils is Directive 75/439/EEC (the Directive), as amended principally by Directive 87/101/EEC, and complemented by directive 91/692/EEC in terms of reporting requirements. The main aim of the Directive is to ensure that minimum environmental standards are applied to the collection, treatment, storage and disposal of waste oils.

The amendments introduced by Directive 87/101/EEC address a part of the overall EC hierarchy for waste management in general (as established in 75/442/EEC) as that hierarchy relates to the treatment of waste oils specifically. It requires that priority should be given to regeneration, followed by combustion, then destruction or controlled storage or tipping of waste oils.

The remainder of the amended Directive deals mainly with the licensing of such operations, permitting and environmental controls. These tie in with the Waste Incineration and Hazardous Waste Directives (see Appendix A).

2.1.2 Definitions in the Directive

"Waste oils" means "any mineral based lubrication or industrial oils which have become unfit for the use for which they were originally intended and in particular used combustion engine oils and gearbox oils and also mineral lubricating oils, oils for turbines and hydraulic oils".

"Disposal" means "the processing or destruction of waste oils as well as their storage and tipping above or underground" (note that this differs from the definition of "disposal" in the Waste Framework Directive – see Appendix A below).

"Processing" means "operations designed to permit the re-use of waste oils, which includes both regeneration and combustion".

"Regeneration" means "any process whereby base oils can be reproduced by refining waste oils, in particular by removing the contaminants, oxidation products and additives contained in such oils".

"Combustion" means "the use of waste oils as fuel with the heat produced being adequately recovered".

2.1.3 Waste oils disposal priorities in the Directive[1]

Article 3 of the Directive[2] requires Member States to give priority to regeneration over combustion, and to combustion over destruction, storage or tipping. Descending this hierarchy may only be justified by "technical, economic and organisational constraints" (TEO constraints).

The relationship between the obligation to take measures to prioritise regeneration, and the assessment of whether there are any constraints to doing so is not clear from the Directive itself. This was the principal consideration in the Commission's case against Germany (see 2.2 below).

2.1.4 Rationale for Regeneration

The preamble to Directive 87/101/EEC, which established the disposal priorities described above, states that:

"whereas regeneration is generally the most rational way of re-using waste oils in view of energy savings which can be achieved;

whereas therefore, priority should be given to the processing of waste oils by regeneration, where technical, economic and organizational constraints allow it..."

Therefore, it appears that the justification for placing regeneration above combustion in the waste oil disposition priorities is that it creates greater energy savings. The accuracy of this assertion is discussed in section 4 below.

2.2 EU Case Law on technical, economic and organisational constraints

The relationship between the obligation to take measures to prioritise regeneration, and the assessment of whether there are any technical, economic and organisational (TEO) constraints was considered by the European Court of Justice (ECJ) in **EC Commission vs. Germany (Case C-102/97)[3]**.

The Commission considered that Germany had failed to take measures to give priority to the regeneration of waste oils. Germany argued that TEO constraints existed that would allow combustion of waste oils as per the second disposal option cited by the Waste Oils Directive.

Germany claimed that the mere existence of TEO constraints was sufficient to avoid the obligation to give priority to regeneration.

[1] *See also the disposal hierarchy of the Waste Framework Directive (75/442/EEC) summarised in Appendix A, para A.2.*
[2] *See Appendix A for Article 3 of Directive 75/439/EEC in full.*
[3] *See Appendix B for further details.*

The Commission argued that in order to avoid the obligation to take measures to prioritise regeneration, the TEO constraints must render impossible the taking of such measures, rather than merely making them more difficult.

The ECJ judged that:

- the obligation to give priority to regeneration is a positive one;
- measures must be taken to promote regeneration within the constraints of TEO factors;
- Member States cannot simply declare that TEO obstacles exist and do nothing further.

In addition, the Advocate General stated that the giving of priority to regeneration must entail tangible steps to favour regeneration.

2.3 Other relevant directives

There are several other relevant EC directives that have an impact on the disposal of waste oils. These include:

- Transfrontier Shipments of Waste Regulation (259/93/EEC)
- Waste Framework Directive (75/442/EEC)
- Waste Incineration Directive (2000/76/EC)
- Hazardous Waste Directive (91/689/EC)
- Integrated Pollution Prevention and Control ('IPPC') Directive (96/61/EC)
- Mineral Oils Excise Duty Directive (92/81/EEC)
- Proposed EU Emissions Trading Directive

For a summary of these directives see Appendix A.

3. Technical aspects

3.1: Production of used Oils in the EU

The consumption of base oils in the formulation of lubricants and other industrial oils in the EU-15 in the year 2000 was 5.3 Mtonnes[4]. This volume can be split according to the use of the final product in automotive and industrial oils. Automotive oils (engine, gear and transmission oils), represent about 65% of the volume, and industrial oils (metal working oils, industrial lubricants, process oils, etc.) 35%[5]. The EU market for automotive oils was about 3.4 Mtonnes in the year 2000 (2.2 engine oils and 1.2 other).

Variable quantities of base oils are consumed and lost during use and/or collection. The amount of collectable used oils therefore, varies according to the usage from 25% up to a maximum value of 60-70%. In the case of automotive used oils the collectable amount is about 48% (60% engine oils and 24% other).

Automotive oils are more suitable for regeneration to re-refined base oils than industrial black oils. Black industrial oils are either non collectable (those contained in metal working fluids) or they contain contaminants that make them difficult to regenerate. On the other hand, light industrial oils can be recovered by simple physical treatment methods.

In the light of this, only automotive oils are considered in this work as being suitable for regeneration. Therefore, the comparison study between regeneration and other disposal methods was done for the total amount of automotive used oils generated. This amount, according to the average collection rate and the total consumption figures given above, could have reached 1.62 Mtonnes in the year 2000.

3.2: Used oils Composition

The composition of used oils is the main element determining its recycle/disposal process options, since it could determine the possibility of recycle as a fuel in power plants or in the re-refining operations. The main composition parameters to be considered are:

- Water content
- Chorine content
- Heavy metals content
- PCB (polychlorinated biphenyls) content

The table 3.1 shows average composition figures taken for used oils collected in France, Germany and Italy.

[4] Wood MacKenzie Supply /Demand study prepared for EUROPIA (2001)
[5] Critical Review of Existing Studies and Life Cycle Analysis on the Regeneration and Incineration of Waste Oils. TN-Sofres (2001)

Table 3.1: Composition of used oils (*)

Characteristic/Component	France[6]	Germany[7]	Italy
LHV (MJ/kg)	39-41	35.5-38.5	-
Density (kg/l)	0.9	-	-
Water (mass %)	6-7	7-10	9
Sulphur (mass %)	0.6-0.7	0.5-0.8	-
Chlorine (mass %)	0.09-0.13	0.09-0.14	0.12
PCB (mg/kg)	-	1.4-24	6
PAC (mg/kg)	-	300-500	-
Cadmium (mg/kg)	<1	0-10	-
Mercury (mg/kg)	<1	<1	-
Chromium	5-10	1-50	-
Lead (mg/kg)	240-338	2-300	-
Arsenic (mg/kg)	<1	<1	-
Cobalt (mg/kg)	8	2-15	-
Copper (mg/kg)	26	3-100	-
Nickel (mg/kg)	6	1-20	-
Vanadium (mg/kg)	-	1-17	-
Zinc (mg/kg)	608-880	500-800	-

(*) Data from 1995/1996. As lead has been removed from gasoline in France and Germany since 1/1/2000, lead levels in used oil can be expected to be much lower today

3.3: Base oils classification

ATIEL guidelines[8] on Base Oil Quality Assurance and Base Oil Interchange divide Base Oils according to their physical-chemical properties into the following six groups:

- Group I
  Base oils containing less than 90% mass of saturates and 0.03% or greater mass of sulphur and having a viscosity index greater than or equal to 80 and less than 120.

- Group II
  Base oils containing greater than or equal to 90% mass of saturates and less than or equal to 0.03% mass of sulphur and having a viscosity index greater than 80 and less than 120.

- Group III
  Base oils containing greater than or equal to 90% mass of saturates and less than or equal to 0.03% mass of sulphur and having a viscosity index greater than or equal to 120.

- Group IV
  Base oils which consist of polyalphaolefins (PAOs)

[6] Etude des filiers de recyclage et de valorisation des huiles usagées. ADEME (1998)
[7] Bilanzierung von Aeltoel-verwertungswegen Umwelt Bundes Amt Berlin (2000)
[8] The ATIEL code of Practice for Developing Engine Oils Meeting the requirements of the ACEA Oil Sequences. Issue No.9. June 2003

- Group V

All base oils not included in the groups I, II, III, IV or VI

- Group VI

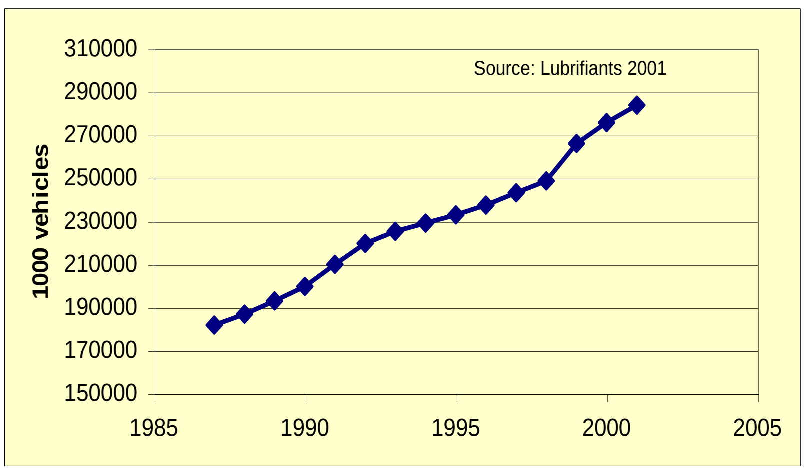
Base oils which consist of polyinternalolefins (PIOs)

3.4: **Reducing the consumption of Base Oils via automotive and lubricant advancements**

Prevention is at the top of the EC's waste management hierarchy[9], and developments in automotive and lubricant technology have helped to achieve extension of oil change intervals, thus also reducing the generation of used/waste oils.

As it can be seen from figure 3.1, the European vehicle park has been consistently increasing in size during the last fifteen years.

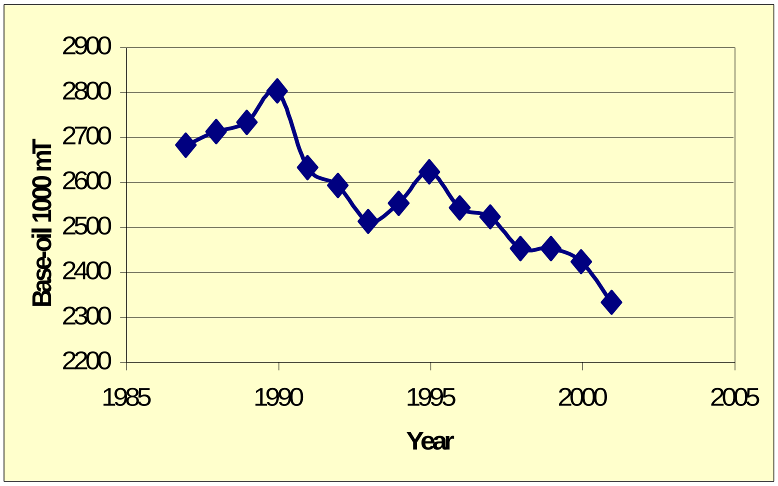
Fig. 3.1: European number of vehicles[10]



In spite of this, during the last decade the oil industry has been working to reduce base-oil consumption for lubricant manufacture (see Fig. 3.2).

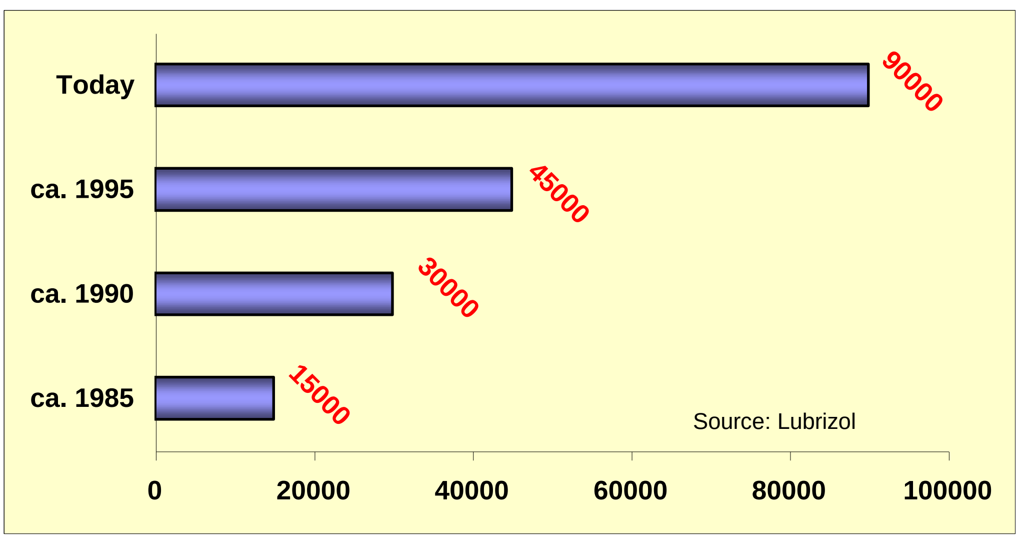
[9] See Article 3 of 75/442/EEC
[10] Source Lubrifiants 2001

Fig. 3.2: Engine oil consumption volume in EU 15 [11]



This has been achieved by formulating higher quality, longer lasting lubricants which enable extended oil drain intervals. A good example of this can be seen in Fig. 3.4 which shows the progressive and increasing oil drain requirements of Volvo trucks from the mid 1980s to the present day.

Fig. 3.3: Oil Drain Intervals for Volvo heavy duty trucks



The situation for heavy duty trucks has been mirrored by passenger car lubricants (see Table 3.2) where oil drain intervals have been increasing while engine power outputs have continued to grow. In addition to this progressive increase in oil drain interval, there has also been a concurrent decrease in the viscosity of lubricants, and hence of base-oils. This enabled either higher net engine power output or lower fuel consumption at a given power output level.

[11] Source Europalub

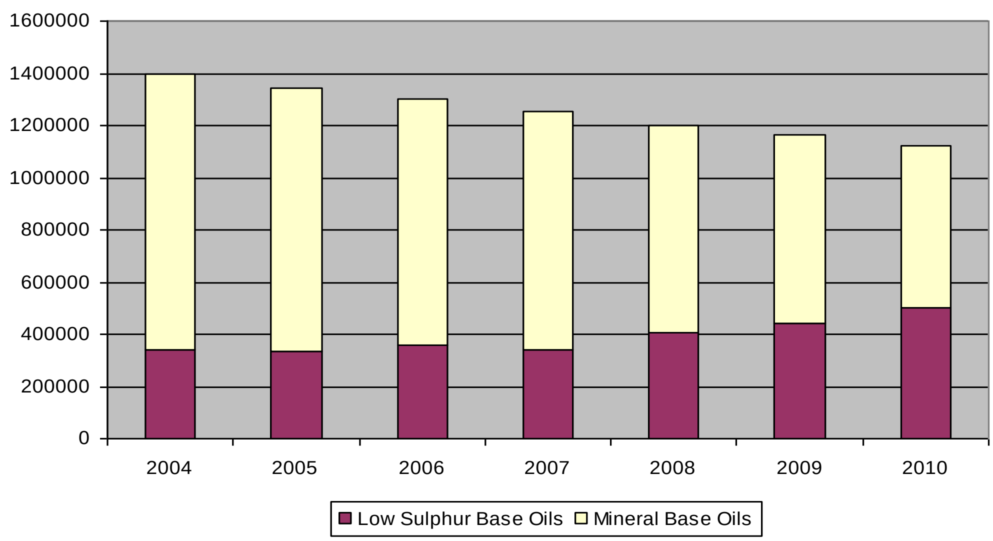
This is particularly apparent in passenger vehicle lubricants where lower viscosity base-oils have been in ever increasing demand. Typically, these tend to be manufactured using modern non-conventional refining techniques or are entirely synthetically created. These classes of base-oil are the most difficult to manufacture using a re-generative approach and high severity re-refining approaches need to be employed.

Table 3.2: Listing of base oil typical qualities and their nominal application performance

ATIEL Group	Sulphur %	Saturates %	Fuel Economy %	Viscosity Index	Oil drain interval (mkm)	Principal SAE Grade
I	>0.03	<90	0	>80	5-10	15W-40, 20W-50
II	<0.03	>90	-1.5	80-120	10-15	5W-30, 10W-40
III	<0.03	>90	-2.0	>120	15-30	5W-40, 10W-40
IV	PAO		-2.5	PAO	+30	0W-30, 5W-40
V	All other Base oils					

Today, ATIEL Group I base-oils can be found in higher viscosity engine oil grades, marine, industrial and process lubricants. Most re-refined base-oils are generally used in only certain of these Group I applications e.g., circulating oils and lower quality engine oils. Re-refined base-oils are not commonly found in the higher quality (low Sulphur) Group II, III or IV applications (see Fig. 3.5).

Fig. 3.4: Anticipated Base Oil Quality evolution for European passenger car and truck lubricants[12]



One of the key reasons for employing increasing quantities of low sulphur Group III and IV base oils is to ensure compatibility of lubricants with new advanced engine after-treatment systems. These systems are necessary for passenger cars and trucks to meet the stringent Euro IV and

[12] ATIEL Presentation on "PCMO and HDDO Volume Trend 2004 - 2010" - Jan 2003

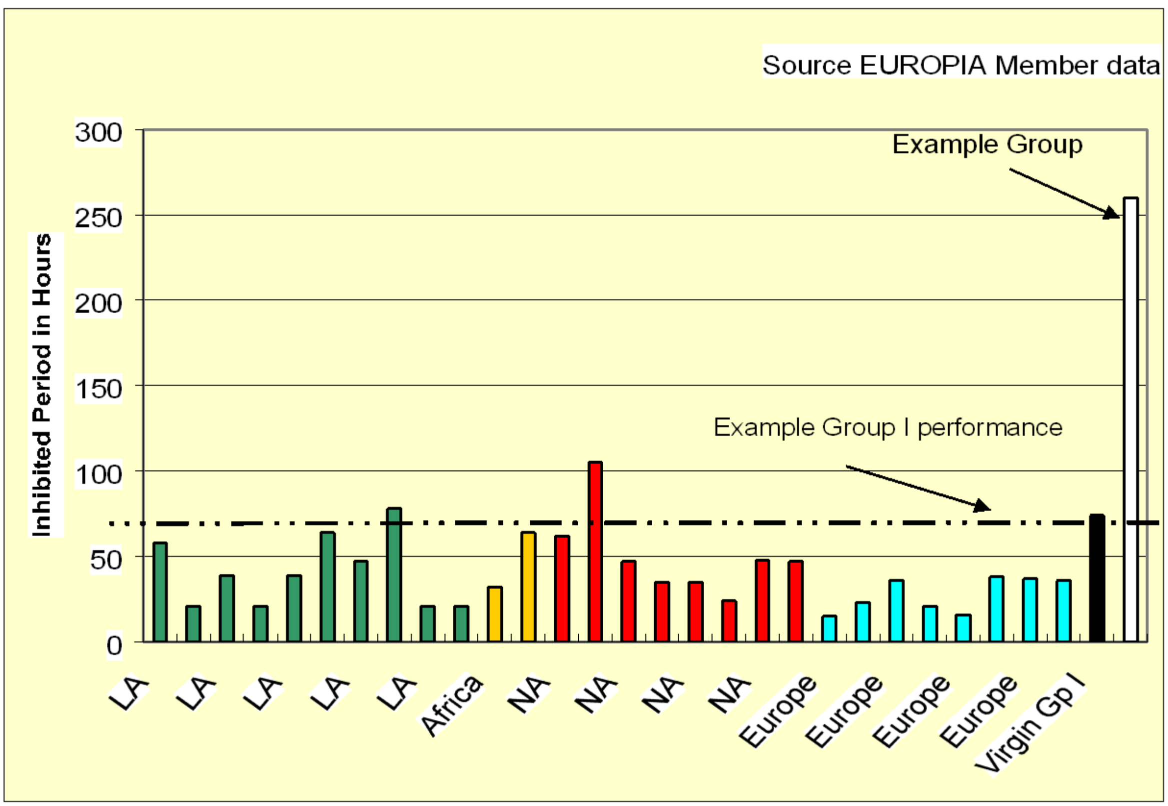
Euro V emissions standards. These emission requirements have been implemented in stages over time to improve air quality throughout Europe.

Clearly, high quality base-oils have a positive impact on the environment and there is a risk that introduction of lower quality re-refined base-oils could jeopardize this on-going improvement.

3.5 Product performance equivalency

It should not be assumed that base stocks made from all regenerative processes are equivalent in performance to virgin base stocks (see Fig. 3.6). Regarding stability, data on most commercial samples of re-refined base stocks collected and tested from around the world during the 1990s showed demonstrably lower oxidation stability than virgin base oils. This translates into shorter oil drain periods and hence increased quantities of lubricant needed plus, ironically, more used oil and used oil filters generated. A range of 29 samples involved in a study encompassing various re-refining processes, including: acid-clay, wiped film evaporator/hydrotreating, vacuum distillation/hydrotreating, wiped film evaporation, propane extraction/hydrotreating, wiped film evaporation/acid-clay, and propane extraction/clay.

Fig. 3.5: ASTM D2440 Oxidation Stability Test Data for a Range of Re-refined Base Oils



In this study, the important oxidation stability parameter of oils was assessed on the basis of the "inhibited period" using the standard ASTM D2440 method. In this method higher inhibited periods relate to better oxidation stability. The performances of re-refined base oils varied widely.

Several of the re-refined base oils had poor oxidation stability; nine of 28 re-refined base oils tested had inhibited periods of less than 25 hours. For comparison atypical Group 1 virgin paraffinic base oil showed an ASTM D2440 inhibited period of over 70 hours and higher performance Group II virgin base oil from North America (there is very little Group II production in Europe) showed an inhibited period in excess of 250 hours. Re-refined base oils are typically marketed as API/ATIEL Group I base stocks.

Normally, the inhibited period would be expected to relate to saturates content and to the concentrations of trace components such as basic nitrogen, acids, metals and perhaps organic chlorides. The rate of oxidation would be expected to depend strongly on the sulphur content and saturates level. This classic relationship is not apparent with the re-refined base oils (see Table 3.3). Also, it was expected that sludging tendency would be a function of metals and PAC content, but again, a relationship is not obvious.

Table 3.3: ASTM D2440, Sulphur and Metals Data for Re-refined Oils

Continent	% Saturates	% Sulphur	Metals ppm	Inhibited period (hours)
Latin America	65.4	0.40	70	58
Latin America	63.3	0.52	71	21
Latin America	63.9	0.51	21.2	39
Latin America	65.3	0.46	9.2	21
Latin America	65.8	0.41	11	39
Latin America	65.2	0.42	47.2	64
Latin America	65.5	0.39	33.7	47
Latin America	65.3	0.45	106.4	78
Latin America	64.7	0.50	5.9	21
Latin America	64.8	0.43	3	21
Africa	74.6	0.40	67.4	32
Africa	66.6	0.62	39	64
North America	87.8	0.30	0	62
North America	87.3	0.30	0	105
North America	82.2	0.07	16	47
North America	85.4	0.10	0	35
North America	85.4	0.09	0	35
North America	85.3	0.16	0	24
North America	82.8	0.12	29	48
North America	88.1	0.07	0	47
Europe	79.2	0.25	12.7	15
Europe	77.4	0.30	1.8	23
Europe	75.8	0.46	33.5	36
Europe	57.9	1.01	44	21
Europe	75.7	0.38	30.2	16
Europe	75.7	0.41	25.4	38
Europe	72.8	0.59	41.6	37
Europe	67.8	0.47	27.4	36
Virgin Group I	***80***	***0.3***	***1***	***74***
Virgin Group II	***98***	***0.03***	***1***	***260***

4. Energy, Environmental and Health aspects

4.1 Energy requirements to recycle used oils

The preamble to 87/101/EEC, the Directive which introduced the priority for waste oil re-generation, states that

> "whereas regeneration is generally the most rational way of re-using waste oils in view of energy savings which can be achieved;
>
> Whereas therefore, priority should be given to the processing of waste oils by regeneration, where technical, economic and organizational constraints allow it..."

This premise supports the basis to give priority to regeneration over any other disposal option.

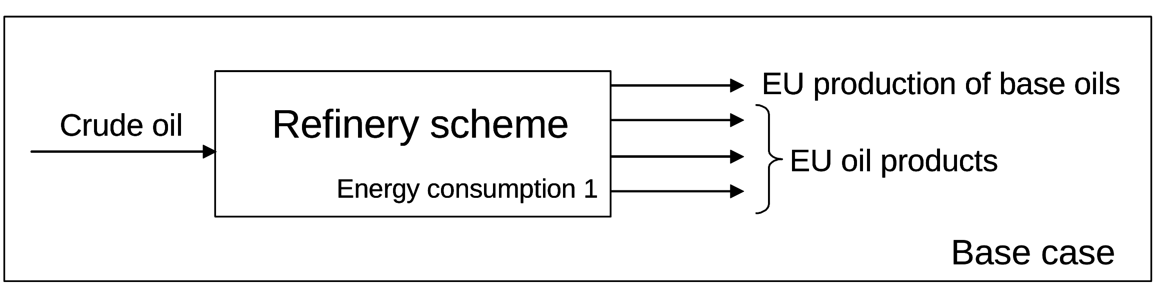
Overall energy and material balances for the EU-15 refining activity with and without collection/recycling of used oils were done in order to analyse the validity of this premise. The following assumptions and constraints were considered:

- Variable crude oil quantities and constant product slate
- Gas oil streams produced in the regeneration processes cannot be used in the formulation of either automotive diesel or home heating oil
- Pretreatment of used oils to remove water and light cracking components is needed for the regeneration processes, whereas recycle as fuel in cement kilns does not require pretreatment.
- The energy consumed in refining is different in each of the cases considered. The changes were done on the internal consumption of heavy fuel oil.

The overall balances were done for the cases shown below:

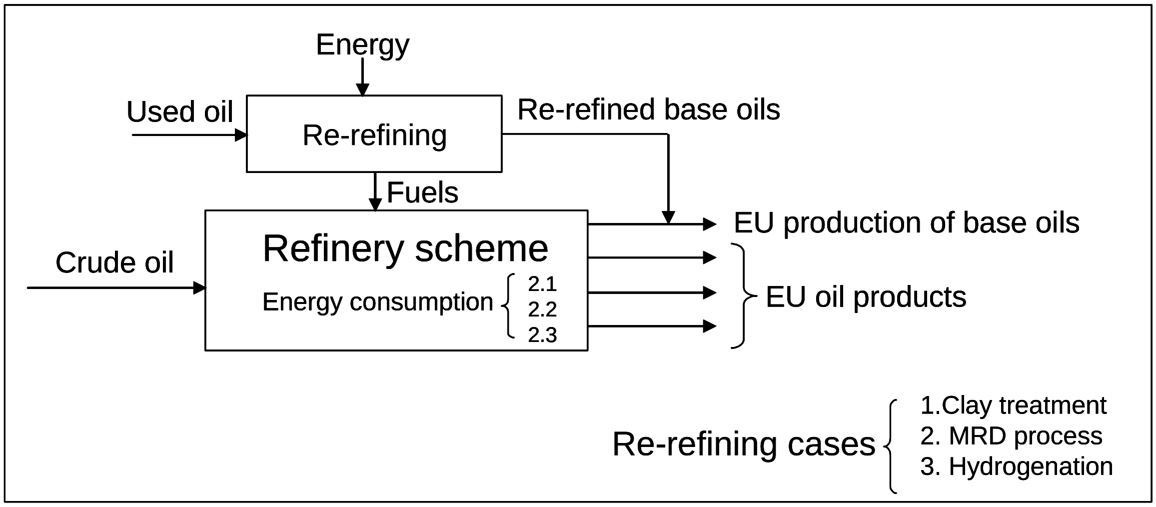
1. Base case:

   The amount of crude oil consumed and the products slate for the EU-15 are taken from the Wood MacKenzie supply demand study[4]. The energy consumption by the different process involved and the overall figure for fuel consumption in the EU refineries are given in Appendix C



2. Re-refining cases:

The situation of recycle of used oils by re-refining was analysed and compared to the base according to the scheme:



The re-refining cases analysed are:

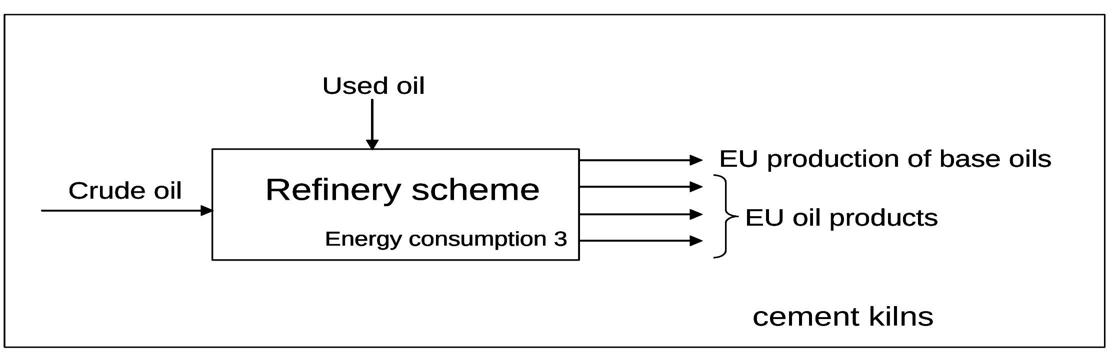
- Clay treatment: Vacuum distillation followed by clay treatment[6]

- MRD process (Mineraloel Raffinerie Dollbergen) taken from the UBA (Umwelt Bundes Amt) study[7] : Low-vacuum distillation followed by high-vacuum flash distillation/thin film evaporation and finishing either by contact distillation with clay or by solvent extraction

- Hydrogenation (Hylube process): De-metallization followed by severe hydrogen treatment and vacuum distillation[6]

3. Combustion in cement kilns

This case assumes that the collected used oil replaces heavy fuel oil in the refinery scheme



The results on crude oil and energy savings are given in Tables 4.1 and 4.2.

Table 4.1: Crude oil savings by recycling of used oil by different methods

Recycle method	Crude oil saved (t/t used oil)	Savings over Clay treatment t/t
Clay treatment	0.86	-
MRD Process	0.93	0.07
Hydrogenation	0.89	0.03
Combustion in Cement kilns	0.98	0.12

Table 4.2: Comparative energy requirements for various final disposition methods

Recycle process	Overall fuel Saved vs. non recycle (kt/year)	**CO_2 emissions saved kt/year**
Clay treatment	18	56.1
Hydrogenation	25	77.7
MRD	30	93.5
Combustion in cement kilns	48	148.7

The refinery schemes considered and material balances are given in appendix D

4.2: Total Crude oil saving by recycling of used oils

The amount of potentially collectable used oil in the EU-15 was about 1.62 Mtonnes in the year 2000 (see section 3.1). The total amount of crude oil potentially saved by recycling of used oils according to the each one of the disposal methods analysed is as follows (Table 4.3):

Table 4.3: Total amounts of crude oil saved by collection and disposal of used oils

Recycle method	Crude oil saved Mt/year	Saving over Clay treatment (Mt)	% potential saving
Clay treatment	1.39	-	87
Hydrogenation	1.44	0.05	90
MRD process[13]	1.50	0.11	94
Comb. cement kilns	1.59	0.20	100

This shows that recycle of used oils by burning in cement kilns gives slightly higher savings than other options. These figures have been obtained for the whole EU-15 situation; therefore, the differences between them could change for the specific situation in each Member State. Since the

[13] Mineraloel-Raffinerie Dollbergen.from Oekologische Bilanzierung von Altoel-Verwentungswegen

average collection rate in the EU is about 70%, there is still scope for substantial improvement by maximising collection.

4.3 Cost for manufacture of re-refined base-oils

The variable cost of converting used oil to re-generated base-oil varies considerably depending on technology used and other operations factors. Table 4.5 lists a summary of the operational cost elements of these various processes. The most costly of these may produce re-refined base-oils of satisfactory quality e.g. PDA/Hydrofinishing, but re-refined base-oils produced from clay processes vary widely in quality and toxicology and frequently do not match virgin base-oil in most application needs.

Table 4.5: Variable operational costs of various re-refining processes.

	Acid/Clay	TFE/Clay	TDA/Clay	TFE/Hydro	TFE/Solvent	TDA/Hydro	PDA/Hydro
Capacity kt/yr used oil	**100**	**50**	**100**	**50**	**50**	**100**	**57**
Operational Cost euro/t used oil	**152**	**221**	**280**	**333**	**308**	**304**	**320**
Finance charge euro/t used oil	**40**	**56**	**53**	**94**	**84**	**81**	**83**
Variable Cost euro/t base oil	**145**	**228**	**328**	**300**	**283**	**282**	**339**

i.e., with a crude oil price of 17 USD (15.5 euros) per barrel, the total variable cost of producing virgin base-oil is **172** USD/mT; at 31 USD (28.5 euros) per barrel for crude, the variable cost of virgin base-oil production is **198** USD/mT[14]. Virgin base-oil variable costs compare well with clay re-generation processes and are much less costly than other more severe re-generation options. In essence, virgin base-oils continue to offer the best ratio quality/cost of production.

4.4 Uses of by-products from regeneration

The increasingly stringent European legislation on exhaust emissions together with the pressure to reduce CO_2 emissions by improving efficiency are driving advances in engine technology and after-treatment systems. These objectives are also driving the development of more stringent fuel specifications. For diesel engines, high pressure fuel injection systems with complex electronic controls are crucial to achieve the new legislative requirements. Fuel injection pressures continue to rise (up to 2000 bar) and multiple injection strategies are also used which require finer tolerances in fuel pumps and injection systems.

[14] UEIL presentation at the IP Meeting - "The Waste Oil Directive - Implications of New Legislation and Opportunities for the Lubricant Industry", London, Nov 5th 2002.

Vehicle manufacturers have reported increased sensitivity of high efficiency engines to contamination in diesel fuel. Vehicle failures are claimed to occur in very short time and the repair requires the complete replacement of the fuel system at a high cost.

In the light of this, EUROPIA believes that the use of gas oils from re-refining processes in the formulation of automotive diesels must be avoided, unless it has been extensively demonstrated by engine and vehicle tests that no damaging effects and harmful emissions are produced

As a general rule, the use of gas oils from re-refining process in the formulation of heating oils should also be avoided unless it is demonstrated that no harmful emissions are produced in the type of boilers used for either domestic or commercial heating

4.5 Toxicological Considerations

Engine oils, particularly Passenger Car Engine Oils, accumulate potentially carcinogenic compounds during use. Metals, from performance additives and from engine wear in-service, have also been reported in used oils. Contamination of used oils by other substances has been observed. This is of particular concern in the case of polychlorinated biphenyls (PCBs). The purpose of this section is to discuss the toxicological issues of used oils associated with those carcinogenic compounds and PCBs, and to assess available toxicological information on re-refined base oils.

There are limited health and environmental data available on re-refined base oils compared to virgin base oils. The majority of the available screening tests for carcinogenic activity have not been validated for use with used or re-refined oils. Other components that are likely to be present in the used or re-refined oils may interfere with the test outcomes and introduce human health issues other than carcinogenicity. Uncertainties still exist over the potential environmental and health hazards of re-refined oils that suggest the need for a case by case evaluation before their use in lubricants.

Mutagenicity tests done with commercial re-refined base oils and virgin base oils showed greater mutagenic activity in the re-refined oils than in the virgin base oils. Re-refined base oils have differences in mutagenic activity depending on the re-refining process used. Hydrotreated re-refined base oils showed lower mutagenic activity than non-hydrotreated samples. This, together with performance data, supports the EUROPIA belief that a minimum re-refining process severity is needed to produce re-refined base oils with similar performance and equivalent health and environmental characteristics to virgin base oils.

The Toxicological aspects of re-refined base oils compared to virgin base oils are discussed in more detail in the Appendix E.

4.6 Waste products resulting from regeneration

The acid-clay regeneration process is still used in Europe and this generates waste material that has proven difficult to dispose of in an environmentally sound manner. Even modern re-generation techniques can, however, also generate wastes e.g. concentrates containing the metals from additives and wear that were in the original used oils, and these need to be finally disposed of. These are typically sent to cement kilns or other safe incineration processes which stabilise these wastes. There are spillage and contact risks involved in handling and transporting this concentrated waste material.

4.7 Optimum regeneration process

EUROPIA believes that the re-refining processes should include, as a minimum, (a) thin film evaporation/vacuum distillation, plus either (b) severe hydrogenation/hydrocracking , or (c) solvent extraction, (a combination of both would be preferable) and hydrofinishing as a finishing step. This must be combined with rigorous feed and product quality controls since significant contaminants in used oils (e.g. PCBs) are not addressed even with the above combination of processes.

5. An alternative to regeneration

5.1 General comment

Although regeneration of used/waste oil can produce base oils of adequate quality, very severe and energy consuming re-refining processing needs to be employed to accomplish this. It should also be noted that even in cases where used/waste oil handling and processing is heavily subsidized, only a small portion of the overall need for base oils will be met by regeneration e.g., only ca. 20-30% of base oils is eventually available for market use in Italy (120 mT/yr regenerated vs. ca. 570 mT/yr demand).

In the report commissioned by DG Environment, the following comparison is drawn amongst the various final disposition options[15].

> *"The amount of the bonus brought by the avoided process is determined by the choice of the substituted process (this is also the case for other wastes with a high calorific value such as plastic wastes).*
>
> *Especially in the case of the incineration of WO with energy recovery, the type of fuels that the WO replace is crucial: fossil fuel, hydroelectricity, thermal electricity, other wastes….*
>
> *This explains that, in the LCAs analysed:*
>
> - *for almost all environmental impacts considered, incineration in cement kilns (where WO replace fossil fuels) is more favourable than incineration in an asphalt kiln (where WO replace gas oil),*
>
> - *a modern regeneration may be, according to the impact considered, more favourable than or equivalent to incineration in an asphalt kiln,*
>
> - *compared to incineration in a cement kiln (where WO replaces fossil fuels), WO regeneration has environmental advantages and drawbacks depending on the impact considered."*

It is worth noting that the conclusions of the report do not favour regeneration over all other disposition routes. In particular, the re-use of used oil as a replacement fuel in cement kilns could prove more environmentally beneficial then regeneration (see section 4.1). In some cases, coal is used as the primary fuel at these locations and used oil is incinerated as a subsidiary fuel. There are significant credits for replacing coal burning from a CO_2 viewpoint since more of this greenhouse gas is produced from coal than from used oil per unit of heat generated. In practice 25% less CO_2 is generated if one metric tonne of coal is replaced by one metric ton of used oil.

5.2 Use waste oil as a fuel in cement kilns

The European cement industry produced about 172 million tonnes of cement in 1995. There are 252 installations producing cement clinker and finished cement (table 5.1).

Used/waste oil is an ideal replacement fuel in the process of cement manufacture. Cement production involves the heating, calcining and clinkering of blended and ground raw materials, typically limestone and clay or shale with other materials to form a clinker[16]. The cement industry

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[15] Executive Summary of "Critical review of existing studines and Life Cycle Analysis on the re-generation and incineration of waste oils", Page 9, TN Sofres, Dec 2001

[16] Cembureau Publication: Alternative Fuels in Cement Manufacture: Technical and Environmental Review

is energy intensive and the dominant energy consumed in cement manufacture is fuel for the clinker. Fuel and electricity represent about 50% of operating costs. Electrical energy represents approximately 20% of the overall energy requirement in cement manufacture[17].

Table 5.1: Number of cement plants in the EU in 1995

Country	No. of cement plants (With kilns)
Austria	11
Belgium	5
Denmark	1
Finland	2
France	38
Germany	50
Greece	8
Ireland	2
Italy	64
Luxembourg	1
Netherlands	1
Portugal	6
Spain	37
Sweden	3
UK	23
Total	252

Traditionally, the primary fuel used is coal, but other fuels are also used, like petroleum coke, heavy fuel oil or natural gas. In addition to these fuels, the cement industry has used various types of wastes as fuel for more than 10 years (table 5.2)

Table 5.2 Breakdown of fuels used in the EU cement industry

Fuel	%
Petcoke	39
Coal	36
Fuel oil	7
Lignite	6
Gas	2
Waste	10

The theoretical energy consumption as fuel for burning to make cement clinker is about 1700 to 1800 MJ/tonne of clinker. The overall energy consumption by the EU cement industry is about 300 PJ (7.2 tonnes of oil equivalent). Controlled burning of used oil as a supplementary fuel in cement kilns can have environmental and economic benefits. The cement industry consumes a large amount of energy and in the process generates very high temperatures approaching 2000 ºC and high combustion zone residence times, on the order of three seconds. (This compares to the EU specifications for hazardous waste incinerators of temperatures of at least 1200 degrees C for at least two seconds.) Mixtures referred to as Secondary Liquid Fuels (SLF) are extensively

[17] Int. Cem. Rev. Jan 1996

used in some regions, depending mostly on economics and these include paints, cleaning agents etc.

Heavy metals present in used oils become incorporated in the clinker and thence into the final cement structure. Since the contents of the kiln are alkaline, they trap hydrogen chloride, sulphur oxides and other acid gases formed in the destruction of chlorine and sulphur containing compounds. Trials with sending PCBs to cement kilns have demonstrated that such materials can be safely destroyed.

As it can be seen from table 5.1 the cement plants are distributed in all EU Member States and their capacity to burn used oils as a replacement fuel significantly exceeds the availability of used oils.

6. Conclusions

1. The fundamental basis used by the European Commission in the directive 87/101/EEC for giving regeneration priority over other disposal options no longer applies. Combustion of used oils in cement kilns or in power plants under controlled conditions provides better, or at least, equivalent benefits in terms of crude oil and energy savings.

2. Considerations on crude oil and energy savings can change with time and location, causing used oil disposal route to change accordingly.

3. An effective collection system is the key step in a responsible used oil management system and is the step which provides the largest environmental benefits.

4. The performance qualities of some commercial re-refined oils analysed have shown to be lower than those of equivalent virgin base oils. Severe hydrotreatment is required for used oil regeneration in order to produce base oils of similar quality to their virgin counterparts.

5. Tests of some commercially produced re-refined oils have shown that they may contain toxic compounds which can be hazardous to human health. Here again, severe hydrotreated, regenerated base oils could achieve equivalent characteristics to virgin base oils.

6. APPENDIX A

EXISITING EC DIRECTIVES THAT IMPACT ON THE DISPOSAL OF WASTE OIL

A.1 Article 3 of Waste Oils Directive (75/439/EEC)

"Where technical, economic and organizational constraints so allow, Member States shall take the measures necessary to give priority to the processing of waste oils by regeneration.

Where waste oils are not regenerated, on account of the constraints mentioned in paragraph 1 above, Member States shall take the measures necessary to ensure that any combustion of waste oils is carried out under environmentally acceptable conditions, in accordance with the provisions of this Directive, provided that such combustion is technically, economically and organizationally feasible.

Where waste oils are neither regenerated nor burned, on account of the constraints mentioned in paragraphs 1 and 2, Member States shall take the measures necessary to ensure their safe destruction or their controlled storage or tipping."

A.2 Waste Framework Directive (75/442/EEC) and the definition of "waste"

2.1 This Directive (as amended by Directive 91/156/EEC) defines "waste", "disposal" and "recovery" by reference to Annexes to the Directive.

"Waste" is defined as "any substance or object listed in Annex 1, which the holder discards or intends or is required to discard".

Annex 1 lists categories of waste. It does not specifically list waste oils, but does include "substances which no longer perform satisfactorily (e.g. contaminated acids, contaminated solvents, exhausted tempering salts, etc)". The Annex also includes a general category of "any materials, substances or products which are not contained in the above categories".

The definition of waste therefore centres on whether a material is <u>discarded</u>. This has caused some argument over if or when a substance has been "discarded" and consequently, whether or not something is "waste".

2.2 This Directive sets out its own hierarchy of disposal options, as follows:

a. firstly, the prevention or reduction of waste production and its harmfulness, in particular by:

- the development of clean technologies more sparing in their use of natural resources;

- the technical development and marketing of products designed so as to make no contribution or to make the smallest contribution, by the nature of their manufacture, use or final disposal, to increasing the amount of harmfulness of waste and pollution hazards
- the development of appropriate techniques for the final disposal of dangerous substances contained in waste destined for recovery;

b. secondly:

i. the recovery of waste by means of recycling, reuse or reclamation or any other process with a view to extracting secondary raw materials, or

ii. the use of waste as a source of energy.

2.3 Annex IIA of the Waste Directive lists disposal operations and these include incineration on land.

Annex IIB lists operations which may lead to recovery, and this includes both oil re-refining and other reuses of oil along with any process where the material is used principally as a fuel or other means to generate energy.

According to these definitions, waste oil is capable of being disposed of or recovered. Equally, recovery includes both regeneration and incineration of waste as a fuel (but not incineration simply as a method of disposal).

A.3 Transfrontier Shipments of Waste Regulation (259/93/EEC)

3.1 This Regulation establishes a system of supervision and control for all movements of waste both between EU Member States and into and out of the EU.

3.2 The Regulation provides for a system of common and compulsory notification for shipments of waste along with a standardised consignment note. The Regulation also draws a distinction between waste for disposal and waste for recovery[18].

3.3 Where waste is to be disposed of after shipment, Member States are able to take measures to prohibit generally or partially, or to object systematically to shipments of waste. The ability to raise objections to shipments of waste applies to the authorities in both the countries of dispatch and destination. They are able to make such objections in order to implement the principles of "proximity", "priority for recovery" and "self-sufficiency" both at community and national level.

3.3.1 The proximity principle requires balancing the need to minimise the distance waste travels against all other factors which might favour or lead to consignments of waste travelling further.

[18] See also Appendix B for a summary of two recent cases on this issue.

3.3.2 Priority for recovery refers to a Member State's duty to implement policies favouring recovery and recycling over disposal (as in the Waste Oils Directive).

3.3.3 A Member State may be able to use the principle of self-sufficiency in order to reduce any environmental burden of dealing with imported waste over and above the burden of dealing with waste generated in their own country.

3.4 Where waste is to be recovered, the Member States have less scope to make objections than they would if the waste was to be disposed of. For example, reasoned objections may be raised if a shipment is not in accordance with national laws and regulations relating to environment protection, public safety or health protection.

3.5 Member States may also raise objections if the ratio of the recoverable and non-recoverable waste, the estimated value of the materials to be finally recovered or the cost of the recovery and the cost of the disposal of the non-recoverable fraction do not justify the recovery under economic and environment considerations.

3.6 A Member State's ability to object to a particular shipment depends on whether the waste is to be disposed of or recovered. Therefore the definitions of "waste", "disposal" and "recovery" are important. These definitions are dealt with in the Waste Framework Directive (see A.2 above).

A.4 Waste Incineration Directive (2000/76/EC)

4.1 This Directive applies to any plant in which "waste" (as defined in Directive 75/442/EEC) or "hazardous waste" (as defined in Directive 91/689/EC) is incinerated. The Directive applies to the incineration of waste oils due to its current status as both waste and hazardous waste (see 6.4 below). The Directive covers both pure incineration plant as well as “co-incineration plant”, where the main purpose of the plant is the generation of energy or the production of material products and in which waste is used as fuel or for the purpose of disposal.

4.2 The Directive provides for the permitting of incineration and co-incineration plants, as well as specifying operating conditions and emission limit values.

4.3 All waste oils incineration will be subject to strict regulation under this Directive from 2006. From that date some commentators argue that:

- incineration costs will increase such that many incinerators will no longer find it economic to incinerate waste oils;
- this may have the effect of precluding existing incinerators such as roadstone coating plants and small waste oils burners in vehicle maintenance and repair workshops, leaving the market exclusively to the cement kiln operators.

A.5 Hazardous Waste Directive (91/689/EC)

This Directive defines hazardous waste by reference to two Annexes. Annexes IA and IB include substances which, although harmful, are less harmful than those listed in Annex II. Mineral oils are listed within Annex IA. Annex II includes substances such as arsenic, lead, cyanides, asbestos and PCBs.

The Directive creates requirements for Member States to ensure that such wastes are properly recorded, labelled and stored or disposed of appropriately.

A.6 Integrated Pollution Prevention and Control ('IPPC') Directive (96/61/EC)

The IPPC Directive lays down measures designed to prevent or, where that is not practicable, to reduce emissions to air, water and land from specified industrial activities.

Any activity that falls within the IPPC Directive will be subject to a permitting and monitoring scheme to ensure compliance with specific emission limits. In many instances, relevant activities and processes must exceed a particular threshold in order for the Directive to apply. For example, in the case of treatment of waste oils, installations for the disposal or recovery of waste oils must have a capacity of over 10 tonnes per day to require permitting under this Directive. However, below this threshold, permitting and monitoring conditions, nonetheless, still apply under the Hazardous Waste Directive and where incinerated, under the Waste Incineration Directive.

A.7 Mineral Oils Excise Duty Directive (92/81/EEC)

7.1 This Directive imposes a harmonised excise duty on mineral oils, which includes motor oils, where the oil is intended for use, offered for sale or used as heating or motor fuel.

Article 3 requires Member States to impose a specific excise duty for the different categories of mineral oils. Exemptions to the duty are listed in the Directive. These do not specifically exempt recycled oils but could apply to such oils where they are used to produce electricity or in combined heat and power plants.

7.2 Under Article 4, it is possible for Member States to introduce other exemptions or reductions in duty if a specific application is made to the Commission and is subsequently authorised by the European Council. The Commission has the discretion to revoke such exemptions if they consider them unsustainable having regard, for example, to Community policy on protection of the environment. This would complement the EU policy on promoting the prioritisation of regeneration, as the Commission would have the discretion to approve an application to exempt or reduce the duty on such oils. Conversely, the Commission also has the discretion to disapprove or revoke any favourable taxation for used/waste oils destined for incineration.

A.8 Proposed EU Emissions Trading Directive

8.1 The draft Directive proposes an EU-wide scheme capping carbon dioxide emissions from specified industrial facilities. Those facilities will be allocated fixed allowances for annual emissions of carbon dioxide. Where facilities emit less carbon dioxide than their allowance, any excess will be tradeable with facilities unable to meet their targets that would otherwise be subject to penalties for non-compliance.

8.2 A preliminary scheme is to commence from 2005 to 2007 and will be administered alongside the IPPC process. It is proposed that the first phase of the scheme will apply to mineral oil refineries, rotary cement kilns with a capacity of 500 tons per day or other furnaces with a capacity of over 50 tons per day.

8.3 Taking measures to reduce carbon dioxide emissions and/or buying carbon dioxide emissions allowances sufficient to meet reducing caps on carbon dioxide emissions will have a cost. It is not clear, however, whether the burning of used/waste oils would be considered a fossil fuel replacement (and hence carbon dioxide reducing) or simply a fossil fuel for the purpose of the EU emissions trading scheme. If it is considered to be the former then burning used/waste oils could give rise to an element of financial benefit. If it is considered fossil fuel, incinerators burning used/waste oils and caught by the EU trading scheme may find the scheme simply increases costs.

APPENDIX B

B.1 EC Commission v Germany (Case C-102/97)

This case considered the relationship between the obligation to take measures to prioritise regeneration, and the assessment of whether there are any technical, economic and organisational constraints (as per Article 3 of the Waste Oils Directive 75/439/EEC).

B.1.1 The Argument

The Commission considered that Germany had failed to take measures to give priority to the regeneration of waste oils. Germany argued that there were a number of technical, economic and organisational (or "TEO") constraints that would allow combustion of waste oils as per the second stage in the hierarchy established by the Waste Oils Directive.

a. An absence of demand for regenerated oils and a decreased demand for motor oil in general, plus an over-capacity in European base oil production along with a low cost of new base oils.

b. Incentives for regeneration may constitute unlawful state aid and would produce unfair disadvantages to other market sectors.

c. Favouring regeneration would create a monopoly for the two remaining regeneration plants in Germany.

d. Allowing first refusal on waste oils by regeneration companies would be unfair to agents collecting the waste oils due to their inability to acquire the best market price.

e. There was a risk that agreements favouring regeneration may create competition law problems.

f. Transport of waste oils to regeneration plants would be costly and present environmental hazards.

g. As there was no duty levied on the sale of lubricants in Germany, it was not possible to create fiscal advantages for regeneration, i.e. by reducing or removing duty on recycled oils.

h. Even assuming that a duty would be imposed under EC Directive 92/81/EEC (on the harmonisation of structures of excise duties on mineral oils), even a complete exemption from the duty, would still provide an insufficient advantage to regeneration companies.

Germany claimed that the mere existence of TEO constraints was sufficient to avoid the obligation to give priority to regeneration.

The Commission argued that in order to avoid the obligation to take measures to prioritise regeneration, the TEO constraints must render impossible the taking of such measures, rather than merely making them more difficult.

B.1.2 The Judgment

The ECJ rejected Germany's arguments. The ECJ's judgment (and the preceding opinion of the Advocate General) concentrated on what constitutes a TEO constraint and the impact TEO constraints have on the duty to take measures to prioritise regeneration, rather than defining the term “priority”.

The ECJ stated that:

- the obligation to give priority to regeneration is a positive one;
- measures must be taken to promote regeneration within the constraints of TEO factors;
- Member States cannot simply declare that TEO obstacles exist and do nothing further.

The Advocate General stated that the giving of priority to regeneration must entail tangible steps to favour this method of treatment.

B.2 EU case law on the meaning of "disposal" and "recovery"

B.2.1 Background

Two recent cases have sought to clarify the meanings of "disposal" and "recovery". The two separate cases are against Luxembourg (case C-458/00) and Germany (case C-228/00).

Neither case has received a final judgment from the ECJ, but in both cases opinions from the Advocate General have been published. The ECJ is not bound to follow the Advocate General's opinion, but it is usually considered highly persuasive.

The two cases involve attempts by Luxembourg and Germany to invoke the provisions of the Transfrontier Shipments of Waste Regulation to prevent shipments where the waste was intended for disposal. Both cases involve waste intended for disposal by incineration.

B.2.2 The Advocate General's Opinion

The Advocate General stated that the question of whether waste is disposed of or recovered through incineration should be determined by the "principle objective" of the incineration plant.

If the principle objective of an incineration plant is to eliminate waste, then this operation would constitute a disposal. If the principle objective is to recover energy (for example in a cement kiln) then such an operation will constitute recovery.

If the ECJ follows this reasoning, then it would be more difficult for a Member State to use the Transfrontier Shipments of Waste Regulation to block any shipments of waste oils (either into or out of the country) for incineration as part of a production process, since this would be considered to constitute a recovery process.

Verol recycling Limburg BV vs. Dutch Minister Van Volkshuisvesting Ruimtelijke Ordening en Milieubeheer

Factual Background

SITA (formerly Verol Recycling Limburg BV**)**, a Dutch company, carried out the collection and processing of hazardous waste. It notified the MVROM, as the competent authority of dispatch, of two planned shipments of waste to be ultimately used by the Belgian cement industry as fuel in cement kilns and as raw material in the production of clinker by cement factories. Consent was given, subject to certain specific conditions concerning the extent to which the purpose of the shipments could be considered to be a recovery operation with use principally as a fuel.

SITA challenged the conditions by way of a complaint to the MVROM and an application for interim measures to the Netherlands Council of State (*Raad van State*), which were both rejected.

SITA then brought an action before the *Raad van State*, which decided to suspend proceedings and make a reference to the ECJ for a preliminary ruling as to:

(1) whether Council Directive 75/442 was to be interpreted as permitting a process for treating waste, in which more than one operation was performed, to be assessed as a whole;

(2) if so, whether the process concerned constituted recovery within the meaning of Annex IIB to the Directive if it resulted in the complete use of the waste;

(3) if not, whether the extent to which the waste contributed to the incineration process was relevant as regards the classification of each individual operation as recovery or disposal; what criteria should be used to assess whether or not the contribution was sufficient for classification as recovery; and whether it was possible to apply national criteria, in the absence of Community rules; and

(4) where one operation must be classified as recovery and another as disposal, how the process as a whole must be regarded.

Held by the ECJ that it must be possible to classify any waste treatment operation as either disposal or recovery, and a single operation might not be classified simultaneously as both.

As a waste treatment process could however, in practice, include several successive stages of recovery or disposal, it followed from the Directive and Council Regulation 259/93 that the treatment process as a whole was not to be assessed as a single operation, but each phase had to be classified separately for the purpose of implementing the Regulation.

When the question of the classification of a waste treatment operation arose for the purpose of implementing the Regulation, only the classification of the first operation which that waste must undergo subsequent to its shipment was relevant in determining the purpose of that shipment.

It followed therefore that, where a waste treatment process comprised several distinct stages, it had to be classified as a disposal operation or a recovery operation, taking into account only the first operation that the waste was to undergo subsequent to shipment. This answer negated the second and fourth questions.

On the final point raised, the calorific value of waste which was to be combusted was not a relevant criterion for the purpose of determining whether that operation constituted a disposal operation or a recovery operation. Member States might, however, establish distinguishing criteria for that purpose, provided that the criteria complied with those laid down in the Directive.

Appendix C. Energy Considerations

C. 1: Energy consumption by refining and base oil production processes

Table C.1 shows the average energy consumption taken to do the energy balances for the several cases studied with and without regeneration.

Table C.1: Energy consumption in refining and specific base oil production processes[19]

Process	KgSRF(*) /t
At. distillation	23.4
Vac. distillation	28.7
De-asphalting	28.1
A. extraction	33.2
De-waxing	68.0

(*) Standard Refinery Fuel

C.2: Breakdown of the fuel used in the EU-15 refining

The breakdown of the refinery fuel used in European refineries is given in Table C.2[20]

Table C.2: Overall Energy and fuel breakdown used in EU-15 refining activity

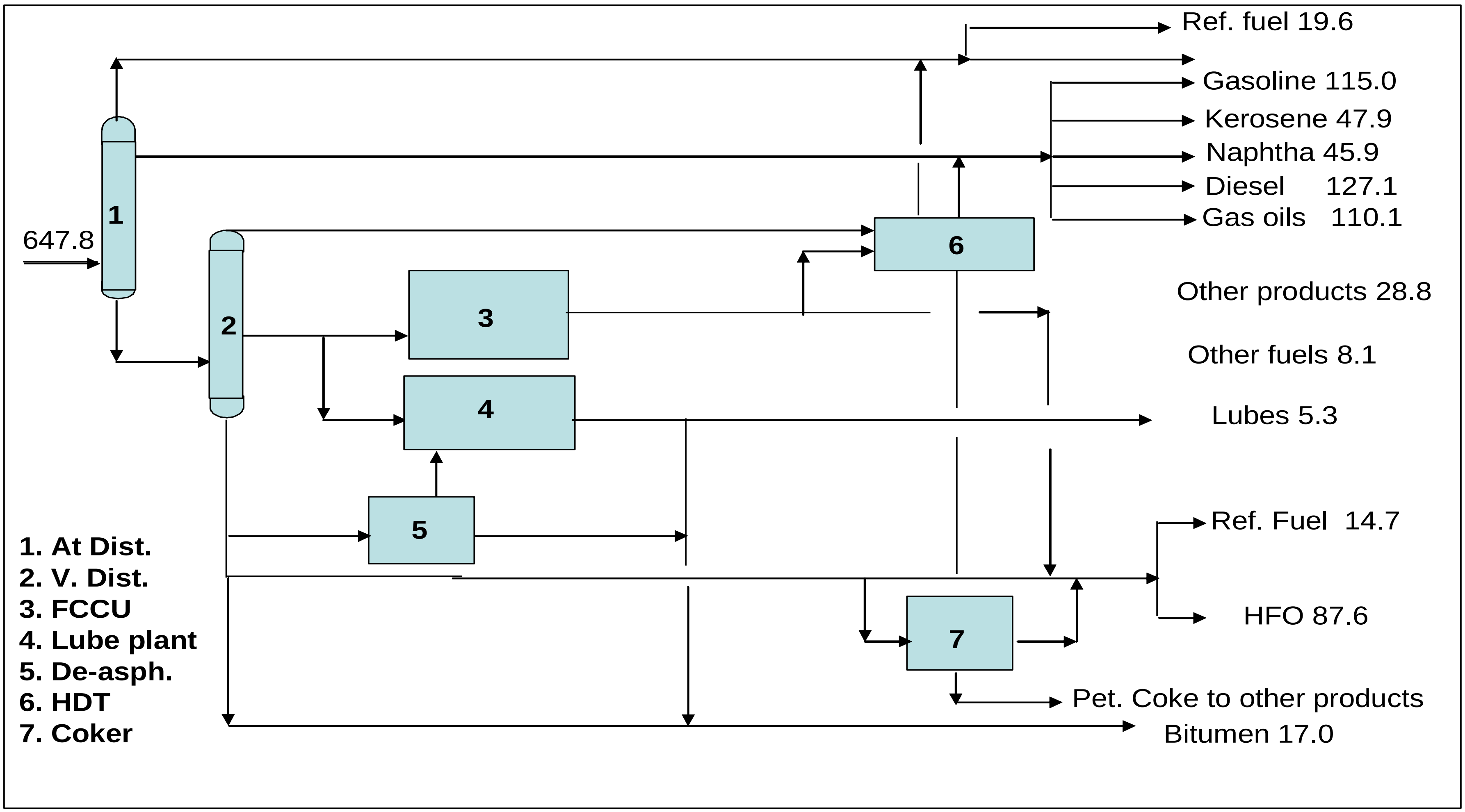
Fuel	**Energy use PJ**
Residual Fuel Oil	590
Petroleum coke	265
Refinery Gas	915
Other	70
Total	**1840 (44 Mt)**

[19] Petroleum Refinery Process Economics. R.E. Maples. PennWell (1993)
[20] Energy Management and Optimisation in the Industry. Study sponsored by the European Commission. AEA Technology (2000)

Appendix D

Material Balances

Used OILS: EU-15 Crude oil and oil products balance (Mtonnes/year)



Used Oils: crude oil, products and energy balances of several disposal options

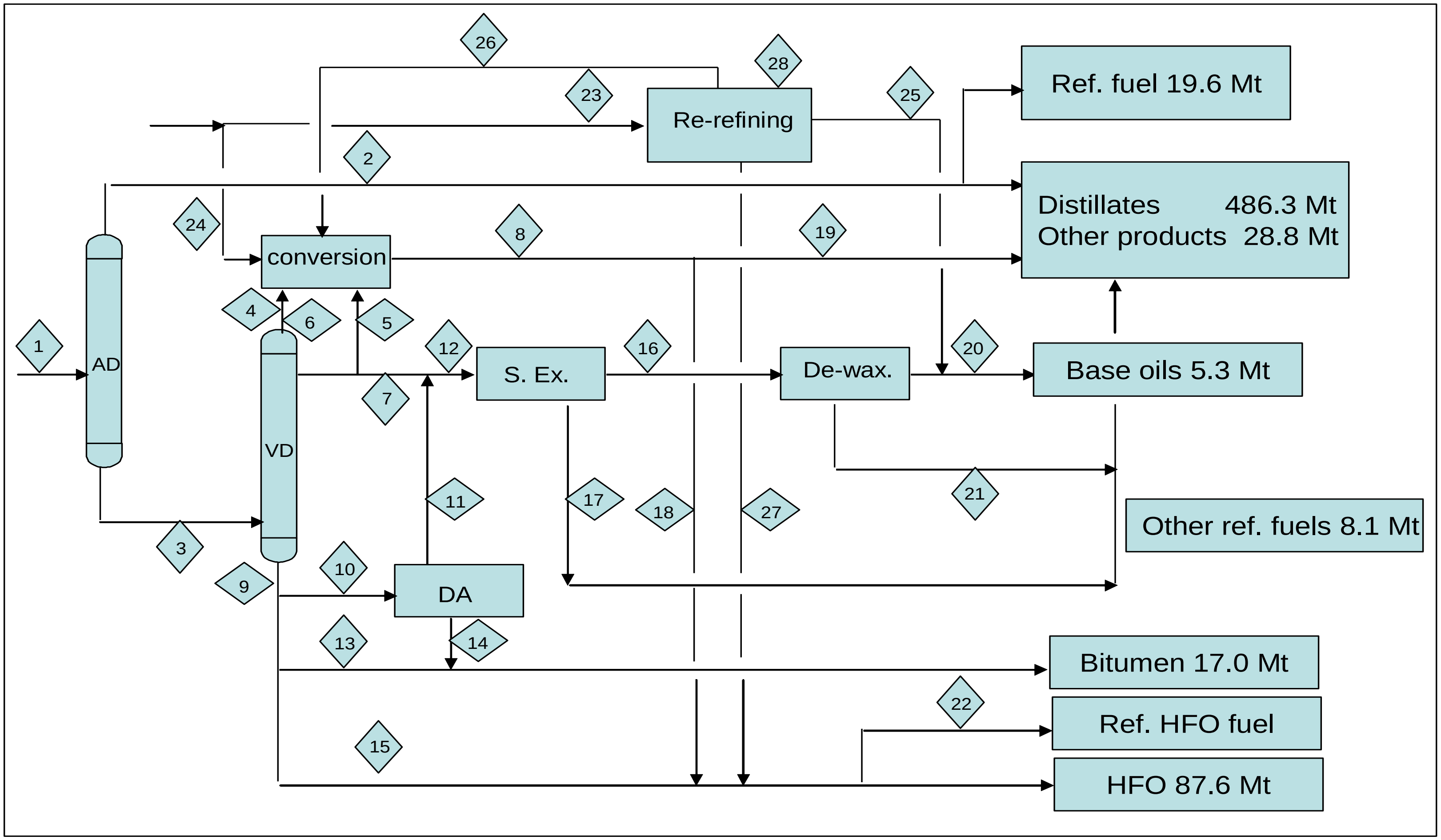


Table D.1: Material balances in Mtonnes/year

Stream No. / Recycle method	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Base case (Mt/y)	647.80	388.68	259.12	15.36	131.34	0.79	5.31	140.13	126.09	5.20	3.12	8.43	14.92	2.08
Clay treatment (Mt/y)	646.43	387.86	258.57	15.44	131.95	0.67	4.52	140.66	125.98	4.42	2.65	7.17	15.23	1.77
Hydrogenation (Mt/y)	646.35	387.81	258.54	15.49	132.39	0.61	4.11	141.07	125.45	4.02	2.41	6.52	15.39	1.61
MRD process (Mt/y)	646.33	387.80	258.54	15.45	132.09	0.65	4.37	140.79	125.88	4.28	2.57	6.94	15.29	1.71
Cement kilns (Mt/y)	646.22	387.73	258.49	15.33	131.01	0.79	5.31	139.77	127.31	5.20	3.12	8.43	14.92	2.08

Stream No. / Recycle method	15	16	17	18	19	20	21	22	23	24	25	26	27	28 energy
Base case (Mt/y)	105.97	6.32	2.11	13.33	126.79	5.36	0.97	14.70	0	0	0	0	0	0
Clay treatment (Mt/y)	106.32	5.38	1.79	12.83	127.83	4.55	0.82	14.55	1.62	0	0.80	0.14	0.30	0.11
Hydrogenation (M/y)	106.04	4.89	1.63	13.06	128.01	4.14	0.75	14.49	1.62	0	1.21	0	0.09	0.19
MRD process (Mt/y)	106.31	5.20	1.73	12.85	127.94	4.41	0.80	14.55	1.62	0	0.95	0.19	0.23	0.10
Cement kilns (Mt/y)	107.19	6.32	2.11	12.06	127.71	5.35	0.97	14.65	0	1.52	0	0	0	0

Appendix E: Toxicological aspects

E.1: Toxicological Considerations

Engine oils, particularly Passenger Car Engine Oils, accumulate potentially carcinogenic PACs during the driving cycle. Metals, from performance additives in the fresh oil and engine wear in-service, have also been reported in used oils, but are not reviewed from a toxicological point of view in this paper. Contamination of used oils by other substances has been observed, and is particularly concerning in the case of polychlorinated biphenyls (PCBs). The purpose of this section is to discuss the toxicological issues of used oils associated with PACs and PCBs, and to assess available information on re-refined lube base stocks regarding these two families of contaminants.

E.2: Testing Methods

Virgin lubricant base stocks are generally derived from vacuum distillate. Vacuum distillate can contain PAC and can be carcinogenic to mouse skin with repeated dermal applications. The condensed ring PAC fraction is removed during modern refining to produce virgin lubricant base stocks that are not carcinogenic. The potential carcinogenicity of these virgin base stocks has been evaluated in several ways, and all have clearly shown that current refining practices remove condensed ring PAC, resulting in non-carcinogenic lubricating oil base stocks.[21,22]

Chronic "skin-painting" studies in mice are the standard method for such assessments, but are time-consuming and costly. Consequently, several short-term carcinogenesis screening tests have been developed. One of these, the IP346 test, is based on the weight of DMSO-extractable material and is currently being used in Europe as a means of determining whether or not distillate oils (additive free) require classification as carcinogenic. A comparison of the results of a large number of carcinogenesis studies to corresponding IP346 data indicates that virgin distillate base stocks do not produce tumors if the DMSO-extractable material comprises less than 3.0 wt%. On the basis of these data, 3.0 wt% has been selected as a means of distinguishing between potentially carcinogenic and non-carcinogenic lube oils for purposes of product classification in Europe.[23]

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[21] ‘Experience gained by the petroleum industry in the conduct of dermal carcinogenesis bioassays’, R McKee et al in Skin Carcinogenesis: mechanisms & human relevance, Alan R Liss, New York pp.363-79 (1989)

[22] ‘Dermal carcinogenicity studies of petroleum derived materials’, R McKee & J Freeman in ‘Health Risk Assessment: Dermal & Inhalation Exposure & Absorption of Toxicants’, CRC Press, Boca Raton, pp263-74 (1993)

[23] EU (1994) Commission Directive 94/69/EC of 19th December 1994 adapting to technical progress for the 21st time Council Directive 67/548/EEC on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labeling of dangerous substances. Official Journal of the European Communities No. L381.31.12.1994

Another widely used assay is the modified Ames test which quantifies mutations in the DNA of bacteria. An upper limit of 1.0 has been set for the mutagenicity index (MI) from this assay for virgin distillate base stocks.[24] Other screening tests that are less well understood include measurement of 3-7 ring PACs, analysis of specific PACs, and the absorbance of ultraviolet light; data from these assays are more limited.

The principal toxicological concern with used oils relates to the potential for dermal carcinogenicity from accumulation of carcinogenic PAC. Such carcinogenic potential has been directly demonstrated in dermal carcinogenesis assays in mice and indirectly through the use of screening tests such as those described above.[25]

E.3: Toxicological Data for Re-refined Base Oils

There is evidence that the PAC content of many re-refined base stocks is higher than that found in virgin base stocks, although lower than in raw used oils that have not been re-refined. A EUROPIA member company has been testing re-refined oils in screening tests since 1985 and has evaluated 130 samples in the modified Ames assay. Although many samples had MI values lower than the test limit of 1.0, over 20% had higher values. The range of MIs for re-refined oils has been found to be higher than for currently marketed virgin base stocks. For example, 53 currently marketed virgin base stocks from seven major producers from the American Petroleum Institute (API) were examined and all had MI values less than 0.8[26] (Fig. E.1).

The IP346 assay has also been used to evaluate re-refined oil samples, but data on re-refined oils are very limited. All 15 samples of re-refined oils examined had IP346 values under 3.0%, as did each of the more than 300 virgin oil samples tested (Table E.1). Note that 12 of the 15 samples in which IP346 was measured were also tested for mutagenic potential. Only one of those 12 had an MI value over 1.

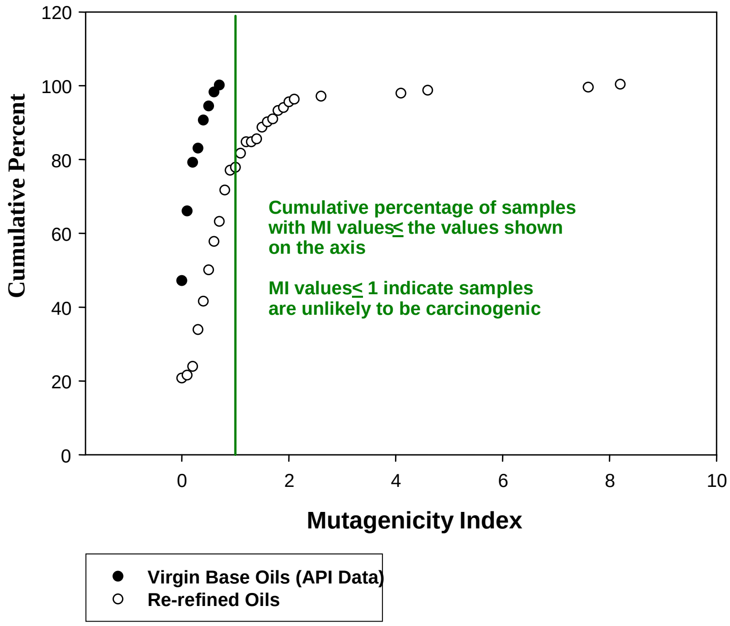
Although the concentration of a limited number of specific PACs is not well correlated with carcinogenic potential of petroleum-derived materials, it may serve as a useful screening assay. The concentration of 21 specific PACs was analysed in 14 samples that also had acceptable values for MI and/or IP346. PAC levels in these re-refined oils were much higher than those in 10 virgin base oils which had similarly acceptable values for MI and IP346. (Table E.1).

[24] 'Estimation of the dermal carcinogenic activity of petroleum fractions using a modified Ames assay' G Blackburn et al, Cell Biology & Toxicology Vol 1: 67-80 (1984)

[25] ' Carcinogenic potential of gasoline & diesel engine oils' R McKee & R Plutnick, Fundamental Applied Toxicology Vol 13 57-65 (1989)

[26] 'Petroleum mineral oil refining & evaluation of cancer hazard' C Mackerer et al, Appl. Occup. Env. Hyg. in press (2003)

Fig.E.1: Comparison of Mutagenicity Index in Samples of Virgin and Re-refined Base Stocks



A limited assessment of the carcinogenic potential of re-refined base stocks was conducted. Five re-refined base stock samples were tested, all of which had IP 346 levels < 3.0 wt% and MI values of < 1.0.

Table E.1 – Summarized Results of Carcinogenic Screening Tests and Analytical Studies of Virgin and Re-refined Base Stocks

Test	Re-refined Base Oil	Virgin Base Oil (EUROPIA data)	Virgin Base Oils (API Data)
IP346	0% > 3 mass% (N=15)	0% > 3 mass % (N~290)	0% > 3 mass% (N=64)
Modified Ames	22% MI > 1.0 (N=130)	0% MI > 1.0 (N~370)	0% MI > 1.0 (N=53)
Specific PACs[27]	mean = 61.8 range = 7 – 160 ppm (N=14)	mean = 0.7 ppm range = 0.1 – 2.0 ppm (N=10)	No data
PCBs	<2 ppm to 3,000 ppm (N=44)	not detected	Not detected

[27] Based on the US EPA list of 13 polycyclic aromatic hydrocarbons

PCBs can be introduced into used oils through contamination by, for instance, old transformer oils. We are not aware of any commercial re-refining technology that can completely remove PCBs. PCBs are known to cause effects such as liver, kidney, gastrointestinal, immunological and dermal toxicity (including chloracne) and are classified by IARC as probable carcinogens. Although European Union Directive 75/439 lays down 50 ppm as the maximum limit for PCB content of regenerated (re-refined) oils, that Directive is believed to be under consideration for amendment. Further, the U.S. Environmental Protection Agency (EPA) (CFR 40 761.20, July 1, 2002) places restrictions on used oils containing "any quantifiable level of PCBs (2 ppm)" and requires combustion in specific types of burners. Among 44 re-refined base stock samples analyzed for PCBs, 35 had less than 5 ppm, the limit of detection for some of the samples. Of the remaining samples, six showed less than 50 ppm PCB, with the remaining three at 509, 955, and 3,000 ppm. The highest samples were from the mid-1980's consistent with the Stiftung Warentest sampling results in Germany[7] during that time frame. Recent analyses (during 2002) by a lab in Africa of nine samples indicated that PCBs were present at levels ranging from 0.2 to 30 ppm. Contamination with PCBs continues to be an area of concern with re-refined oils and requires frequent monitoring and controls for all used oils used as feed stocks in re-refining plants.

A further analysis examined the effectiveness of hydrotreatment as a processing step for used oil re-refining. Among the 130 samples that underwent modified Ames testing, the actual re-refining processing history was known or could be reasonably inferred for 87. Of these, 56 were hydrotreated (almost all wiped film - HT), whereas the remaining 31 were re-refined by other processes including acid/clay, distillation/clay, and thermal deasphalting/fraction/clay. The results show that, directionally, the hydrotreated samples have lower MI values than the non-hydrotreated samples, but that both have MI values higher than those in the virgin base oils (table E.2).

Table E.2 – Assessment of the Effectiveness of Hydrotreatment as a Processing Step in Used Oil Re-Refining

Virgin Base Oils (API Data)	**HT Re-refined Base oils**	**Non-HT Re-refined Base oils**
Mean MI = 0.2 ± 0.2 (N = 53)	mean MI = 0.6 ± 0.5 (N = 56)	Mean MI = 0.9 ± 0.7 (N = 31)
0% MI >1	16% MI > 1	26% MI > 1

This serves to reinforce the belief that a minimum re-refining processing sequence is necessary to produce re-refined base stocks generally equivalent in consistency, safety, and product performance qualities to virgin base oils

produced from crude oils in conventional lube refineries (See section 4.7). Simply including some form of “hydrotreating” in the re-refining processing sequence could very well be inadequate to remove, or reduce potentially hazardous contaminants to acceptable or safe levels.

All of the above information only provides a guide to the acceptability of re-refined oils for use in lubricating oils. There are very few health and environment data available on re-refined oils compared to virgin base oils and the majority of the available screening tests for carcinogenic activity have not been validated for used and re-refined oils. Other components/contaminants are likely to be present in re-used and re-refined oils that may interfere with the test outcomes and introduce human health issues other than carcinogenicity. A number of uncertainties thus still exist over the potential health and environmental hazards of re-refined oils which suggest a need for caution and case by case evaluation before their use in finished lubricants.

Appendix F

USED OIL TERMINOLOGY -- As Employed generally in this report*

ADEME
Agence de l'Environment et de la Maitrise de l'Energie- French Environmental Agency

ATIEL
Technical association of the European lubricants industry (Association Technique de l'Industrie Europeenne des Lubrifiants)

Base Oil
A Base Stock or a blend of two or more Base Stocks used in producing finished lubricants. Usually blended in combination with additives to produce finished lubricants

Base Stock
A hydrocarbon lubricant component, other than an additive, that is produced by a single manufacturer to the same specifications (independent of feed source or manufacturer's location), and that is identified by a unique formula number or product identification number, or both.

Coking
Resid upgrading process. By severe thermal cracking, it completely converts residual oils to coke and more valuable liquid products**.**

Collection
Gathering of used oils and likely transportation to a location where either Disposal or, more typically, Re-use or Recovery operations take place.

Combustion
The application of Used Oils as fuel, with the heat produced being adequately recovered.

CONCAWE (CONservation of Clean Air and Water in Europe)
Organization of European Oil Industry for environment, health, and safety issues. It now covers some product quality aspects as well.

*There are confusing and sometimes conflicting uses of many used oil terms in various circles. Therefore, in order to improve the effectiveness and efficiency of used oil communications for EUROPIA members, the definitions within this listing should be used.
Many of the terms here are based on Standard Terminology Relating to Petroleum, Petroleum Products, and Lubricants ASTM D4175 -01. Some terms flow from EU and other governmental uses, whereas some were extracted from dictionaries.

If it is concluded that the predominant use outside of EUROPIA is different from the definition(s) here, then this listing will likely be updated accordingly.

Cracking

Process of thermal breaking of petroleum molecules, typically facilitated by a high activity catalyst, into shorter molecules aimed to extract low boiling fractions such as gasoline and other petroleum products.

Disposal

Result of operations on a Used Oil after the act of Collection. It includes results of either Re-use/Recovery operations or release of Used Oil into the environment via a variety of steps, including but not limited to discarding, dumping, landfilling or burning without energy recovery.

Disposition

Synonym for Disposal

Distillation

The process of boiling a liquid containing two or more components and the condensation of the vapour. Separation by vapour pressure, molecular weight, density, and boiling point.

G. E. I. R.

Groupement Europeen de l'Industrie de la Regeneration. European Association of Regeneration (Re-refining) Industries

IP 346

The IP 346 method is a gravimetric measure of dimethylsulfoxide (DMSO) extractable material , including PACs, from lubricant Base Stocks.

Laundering

Equivalent to Reclaiming

Life Cycle Analysis (LCA)

Per ISO 14040, "LCA studies the environmental aspects and potential impacts throughout a product's life (i.e. cradle-to-grave) from raw material acquisition through production, use and disposal. The general categories or environmental impacts needing consideration include resource use, human health, and ecological consequences." Sometimes referred to as a "Well to Wheels" analysis.

(Used Oil) Management

All operations on a Used Oil after it has reached the end of its useful life for its originally intended purpose. It encompasses Collection as well as subsequent Dispositions for the Used Oil, i.e. Disposal to the environment, Re-use, or Recovery.

Modified Ames Assay

The Modified Ames Assay measures the mutagenic activity of a material, (e.g., lubricant Base Stock) in a *Salmonella* bacteria strain(s). The final result is termed **the** *"Mutagenicity Index" or MI.* The MI is the slope of the dose response curve relating Mutagenicity to the dose of test material extract added. It is a measure of mutagenic potency.

Mutagenicity

Refers to the induction of permanent transmissible changes in the amount or structure of genetic material of cells or organisms. These changes, or "mutations," may involve a single gene or gene segment, a block of genes, or an entire chromosome(s).

PACs = Polycyclic Aromatic Compounds, sometimes PAHs (polyaromatic hydrocarbons) or PNAs (polynuclear aromatic compounds).

Polycyclic, fused-ring, or condensed-ring aromatic compounds. They can be created during high temperature processes, as in combustion or thermal quenching processes. Some of these compounds have been reported to cause skin cancer in humans under conditions of poor hygiene, prolonged repeated contact, and exposure to sunlight.

PCBs = PolyChlorinated Biphenyls

A class of synthetic chemicals consisting of a homologous series of compounds beginning with monochlorobiphenyl and ending with decachlorobiphenyl. They do not occur naturally in petroleum, but are found as contaminants in used oil (often from used transformer oils). They are not permitted in products for General Motors (LS2 standard) and for some other customers.

PDA = Propane de-asphalting

Reclaiming:

The use of cleaning methods during Recovery primarily to remove insoluble contaminants, thus making the oil potentially suitable for further use. The methods may include settling, heating, dehydration, filtration, or centrifuging.

Reconditioning

Equivalent to Rejuvenation.

Recovery

The act of obtaining usable substances from possibly otherwise unusable sources. Operations other than Disposal to the environment or Re-use that occur after the Collection of Used Oils, i.e. Regeneration or Reprocessing.

Recycle/Recycling
Action by which the oil that has become unsuitable for its original intended use is either used as fuel or processed to regain the original lube properties and fuels.

Regeneration
The preparation of Used Oils for application as either a (component in a) finished lubricant, or as a Base Stock. Encompasses both Rejuvenation and Re-refining processes.

Rejuvenation
The preparation of Used Oil for re-application as a lubricant. Rejuvenation involves Reclamation activity as well as, generally, blending of new additives to replace those that had been depleted during the Used Oil's original use.

Reprocessing
The preparation of Used Oil for application as a fuel. Reprocessing may involve blending and/or Reclamation activities such as settling and filtration, as well as refining processes, including Distillation, thermal cracking, such as fluid or delayed Coking, or catalytic Cracking.

Re-refining
The use of refining processes during Recovery to produce Base Stocks for use in finished lubricants or in related products. Re-refining may include one or more of the following: Distillation, hydrotreating, or treatment employing acid, caustic, solvent, clay, or other chemicals, or combinations thereof.

Re-use
The application as a petroleum product of a Used Oil (i.e. oil that has become unsuitable for its original intended use) to the same family of uses (albeit less severe than the original use) or another use -- typically without additional treatment, blending, or processing. Includes use in a less severe lubrication application or burning for energy recovery. Follows a Collection process.

TDA = Thermal de-asphalting

TFE = Thin Film Evaporation

Treatment
Any method/technique short of Recovery used to change the physical, biological, or chemical characteristics of a Used Oil, making it safer to store, transport, or Dispose**.**

U.E.I.L.
Union of European Independent Lubricating Oil Producers.

Used Oil
Used oil is typically defined as a petroleum or synthetic based oil from industrial or engine and power-train sources that had been used for lubricating or process purposes and has become unsuitable for its original purpose. Generally, such an oil has been used in a piece of equipment (for example, a compressor, pump, engine, gearbox, or turbine), and is suitable for Recycling or Re-use. It does not include process wastes from oil refineries, drilling muds, solvents, or transformer oils. Used lubricating oils represent, in effect, an intermediate step on the way to the ultimate fuels (energy recovery) Disposition for virtually all hydrocarbons derived from crude oil.

VOC
Volatile organic compound (organic hydrocarbons)

Waste Oil:
A Used Oil that contains comparatively high levels of one or more specific contaminants such that it may be considered unsuitable for normal Combustion (Re-Use) or Recovery Dispositions, but rather considered necessary to be consumed in cement kilns, special incinerators, or in other Dispositions adept in handling such contaminated material. The contaminant limits referenced above might include PCBs above 50 ppm, or total halogens above 4,000 ppm. The term Waste Oil is sometimes used as a synonym for Used Oil.

Appendix G

LIST OF SYNONYMS AND SUB-SETS

SYNONYMS

- Reconditioning = Rejuvenation
- Reclaiming = Laundering

- Re-use = Includes Used Oil burning for energy recovery (Combustion).

SUB-SETS

- Management = Collection, Disposal

- Recycling = Collection, Re-use, Recovery

- Disposal/Disposition = Recycling/treatment/landfilling, dumping, discharging, or burning without energy recovery

- Recovery = Regeneration, or Reprocessing.

- Regeneration = Rejuvenation/Reconditioning, Re-refining to lube Base Stock

- Rejuvenation/Reconditioning = Reclaiming/Laundering, blending, re-additizing (to finished lubricants)

- Reprocessing = Reclaiming/Laundering, refining, blending (to fuel products)

Footnotes for "Used Oil Management - EUROPIA Terminology Diagram" on the next page:

(1) Applicable for Used Oils low in PAC content -- generally those that have been in non-gasoline engines, or low temperature industrial oil applications.

(2) Waste Oil is a Used Oil that contains significantly high levels of one or more specific contaminants, e.g., PCBs over 50 PPM, and generally should not be used in many Re-Use or Recovery Dispositions

Appendix H

Used Oil Management - Terminology Diagram