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ECONOMIC AND ENVIRONMENTAL ASPECTS OF USED OIL TREATMENT – PART I

Key words:

Waste Disposal Act, regeneration of waste oils, vacuum distillation.

Abstract

This article presents legal regulations connected with the recycling of waste oil as well as, an organizational structure of Eurobac sp z o. o. company and the process of waste oil regeneration. The system presented in the study has been modified using an original software for control of the entire refinery designed by the authors of this study including vacuum distillation up to 150ºC (first step), vacuum distillation up to 350ºC (second step), and the filtration of the ready product on filtering plates (third step). This is the first of a series of planned publications.

Introduction

Nowadays, more and more attention is being focused on the reduction of energy production using fossil fuels, including coal, oil, and natural gas. This is caused by progressive degradation of the natural environment, global warming, and natural resources depletion.

New energy sources are being searched for due to increasing energy demand (e.g., Renewable Energy Sources – OZE) with simultaneous attempts to effectively utilize conventional energy sources.

One of the methods used for increasing the efficiency of using conventional energy sources is the recycling of waste oil products.

The goal of this work is to provide a description of the waste oil refining process based on Used Oil Refining of Eurobac sp. z o.o. in Trzebinia.

The study presents regulations concerning the management of substances in the form of oil waste products. The authors also present a method for waste oil recycling currently used in our industry.

This study also includes the results of investigations on the operation and maintenance of the discussed system.

1. Polish laws on waste oil recycling

The Act of 11 May 2001 sets out the obligations of manufacturers in the field of the management of some waste as well as product fees and deposit fees (Journal of Laws 2001 no. 63 item. 639) to prevent the production of oil waste products, to reduce their negative impact on the environment, and to provide a high level of the recovery and recycling of waste derived from these products. A manufacturer is obliged to reach a certain level of recovery and waste recycling, i.e. at least 35% of recycling and 15% of recovery for engine and transmission lubricants. According to the Act of 2014, manufacturers should reach the level of recycling equal to 82810 tons and recovery equal to 35490 tons in Poland.

According to the PN-C-96050 norm, used lubricating oils include oils of petroleum or ester origin as well as oil-water mixtures, which have lost their functional qualities in service conditions and cannot be used any more according to their destination, though they…'must not contain harmful substances which could impair the process of regeneration or constitute enrichment of the regenerate' [9, 10].

Used lubricants are considered to be hazardous waste. The process of burning, especially of gasoline, is accompanied by a process of pyrolysis of hydrocarbons, which results in the occurrence of polycyclic aromatic hydrocarbons including benzoapiren, which is considered to have a carcinogenic effect. Operation of an engine involves the occurrence of changes in the content

of hydrocarbons of a lubricating oil. These are the refining agents that undergo most changes, which involve a transition into a different physical-chemical structure. Generally, these changes lead to particle destruction and a transition into simple substances causing production of calcium, magnesium, carbonates, sulphides, metal oxides, and more complex substances due to the chemical effect of inorganic substances on hydrocarbon destruction products

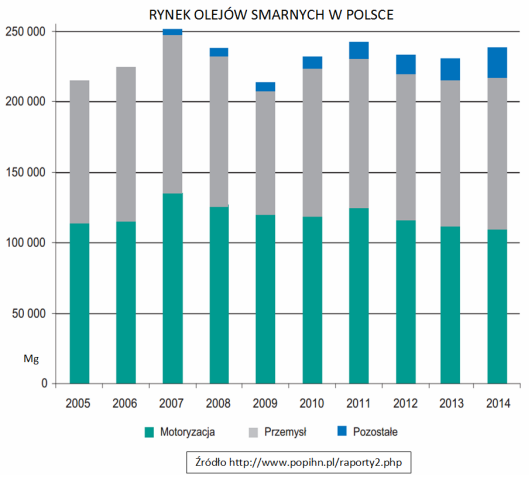

Fig.1. Market of lubricating oils in Poland

There are also products of the thermal and mechanical disintegration of polymers. Added metals from the wear of engine components mean that these lubricants contain a significant amount of elements from the Mendeleev's Table. Since used oils contain polycyclic aromatic hydrocarbons, some products produced as a result of changes in refining agents (zinc diphosphates, high sodium acidified phenolates, sulphur phenolates, phenols with steric hindrance) and heavy metals (Mn, Fe, Pb, Zn, Cu, Ni, Cd, Cr), having a harmful effect on the environment, in particular on human health, they need to be collected and utilized in the least harmful manner to the natural environment [7].

Directive 087/101 EEC Art. 1.1 defines used oil as any lubricating or industrial oil of mineral origin that cannot be used again for the purpose for which they were designed. These are mainly used lubricating oils for combustion engines, transmission lubricants, mineral lubricating oils, hydraulic oils, and turbine oils.

2. Regulations for waste oils management

Integration of Poland with the European Union has forced the introduction of many regulations in the area of waste management [2].

2.1. EU Acts for waste management

EU legislation for waste management can be divided into the following groups:

- Directives, regulations, decisions, resolutions affecting the law of a particular member country in the field of municipal solid waste management;
- Directives, regulations, decisions and resolution of general application; and,
- Directives, regulations, decisions, and resolutions concerning a particular stream of wastes.

In the field of waste management:

- Hazardous wastes combustion – Council Directive 94/67/WE of 16 December 1994;
- Waste storage – Council Directive1999/31/WE of 26 April 1999;
- Municipal solid waste management – Council Directive 2000/76/WE of the European Parliament and Council of 4 December 2000.

The most important legal acts include the following:

– General requirements:
  - Decision of Commission 2000/532/WE of 3 May 2000 r., to replace decision of Commission 94/3/WE establishing a list of waste according to Art 1 of Council Directive 75/442/EWG on hazardous waste and Council Decision 94/904/WE establishing the list of hazardous wastes according to art 1 of the act;
  - Council Directive 75/442/EWG on waste (further a framework directive) – amended and extended by Council Directive 91/156/EWG, Council Directive 91/692/EC, Commission Decision 94/3/WE (the so called European Catalogue of Waste and Decision of Commission 96/350/WE;
  - Council Directive 94/31/WE of 27 June 1994 amending Directive 91/689/EWG in the matter of hazardous waste;
  - Council Directive 91/68EWG on hazardous waste amended by Commission Decision 2001/118/WE, 2001/119/WE and 2001/573/WE;
  - Council Regulation 259/93/EWG of 1 of February 1993 on supervision and control of wastes shipment inside and outside the European Union, as amended by Council Directive 97/120/WE and Commission Decision 99/816/WE.

– Particular types of wastes:
  - Council Directive 75/439/EWG of 6 June 1975 on utilization of waste oils, as amended by Council Directive of the European

Parliament and Council 87/101/EWG and 91/692/EWG AAND Directive of the European Parliament 2000/76/WE;
- Council Directive 96/59/WE of 7 September 1996 on disposal of polychlorinated biphenyls and triphenyls (PCB/PCT);
- Directive of the European Parliament and Council 2002/95/WE of 27 January 2003 on restrictions to use some hazardous substances in electrical and electronic equipment;
- Directive of the European Parliament and Council 94/62/WE of 30 December 1994 on packaging and packaging waste;
- Council Directive 86/278/EWG of 12 June 1986 on environment protection especially soils, for use of sediments in farming, as amended by Council Directive 91/692/EWG;
- Directive of the European Parliament and Council 2000/53/WE of 18 September 2000 on vehicles withdrawn from use, amended by decision of Commission in 2002/525/WE;
- Directive of the European Parliament and Council 2002/96/WE
- of 27 of January 2003 on used electronic and electrical equipment (WEEE).

The basic document of the European Union concerning the management of waste oil is Council Directive 87/101/EWG of the 22 December 1986 amending Directive 75/439/EWG of 16 June 1975, as amended by Council Directive 87/101/EWG of 22 December 1986 on utilization of waste oils.

The aim of this directive is to ensure the safe collection and utilization of waste oil, and utilization means recycling (regeneration and/or combustion other than for destruction purposes).

In order to achieve the set goals, this directive recommends that member countries of the European Union should do the following:
- Undertake appropriate steps in order to guarantee collection and utilization of waste oil avoiding causing any devastation or damage to the natural environment and humans.
- Take actions to promote construction of companies to deal with the collection and utilization of waste oil and decide on its collection, utilization, and use.
- Guarantee the combustion of waste oil in appropriate conditions from the point of view of environment protection and according to the rules of this directive given that the combustion is technically and economically possible. Impose an obligation to apply for permits to be granted in the field of collection, utilization, and reuse of waste oils.
- Make sure that technologies to be used for regeneration or combustion of waste oil are possibly the best without bearing too high costs.
- Provide a user of waste oils with the possibility to utilize it safely instead of passing it to unauthorized entities.

- Prevent oils being mixed with other dangerous substances.
- Oblige units that collect and use waste oils to evidence this activity.

At the same time, the directive introduces a ban on the following:

- Dumping oils into inland water reservoirs, the sea, or canal systems;
- Storing or dumping waste oils in a way that poses a threat to contaminate soil or any uncontrolled dumping of recycled waste; and,
- Waste oils treatment of any kind that causes air pollution exceeding the level recommended by applicable laws.

2.2. Polish Laws

Basic environmental protection laws are included in the following:

- Environment Protection Act of 27 04.2010, Journal of Laws of 2013, item. 1232, as amended;
- Waste Disposal Act of 14 December 2012 Journal of Laws 2013 item 21;
- Regulation of the Minister of the Environment regarding catalogue of waste, Journal of Laws of 2014, item 1923;
- Regulation of the Board of Ministers of 9 November 2010 on enterprises posing a threat to the environment Journal of Laws 2010 no.213 item1397;
- Regulation of the Environment Protection Minister of 12 December 2014 on document forms used for the needs of waste evidencing Journal of Laws 2014 item 1973;
- Regulation of the Minister of Economy and Work of 4 August 2004 on detailed management of waste oils, Journal of Laws of 2004 no. 192 item 1986;
- Regulation of the Environment Minister of 5 November 6 2001 on detailed conditions to be met by a manufacturer for production of lubricating oil with a share of domestic base elements derived from regeneration in order to include them into actually reached recycling level, Journal of Laws 2001 no. 131 item 1475;
- Act of 11 May 2001 on requirements to be met by manufacturers in management of some wastes, product fee and deposit fee Journal of Laws 2001 no. 63 item 639;
- Act of 13 June 2013 on management of packaging and package wastes Journal of Laws 2013 item 888;
- Regulation of the Minister of the Environment of 27 October 2014 on annual levels of recovery and recycling of lubricant substances, additives and anti-freezing agents, Journal of Laws 2014 item 1598;
- Act of 3 October 2008 on exchange of information on the natural environment and its protection, participation of society in environment

protection and assessment of the impact on the environment, Journal of Laws of 2008 no. 199 item 1227;
- Act of 11 September 2015 regarding used electrical and electronic equipment, Journal of Laws of 2015 item 1688; and,
- Act of 24 April 2009 on batteries and power storage units, Journal of Laws of 2009 no.79 item 666.

The Waste Disposal Act defines manufacturers and users of wastes and classifies waste, and indicates goals and rules of waste management specified by particular directives of the European Union including waste oils.

According to Art. 39 of Act of 27 April 2001, waste oils should first be subjected to recovery through regeneration, viewed as any process in which base oils can be manufactured by refining waste oils, in particular, by removing contamination, oxidation products, and additives included in oils.

A waste oil manufacturer is obliged to use such manufacturing methods and raw materials that prevent production of wastes or to maintain it at a possibly low level as well as decrease the negative impact on the environment and human health.

If a manufacturer who produces waste in the form of waste oil is not able to meet the requirements set out in Par. 1 or Par. 2, they should pass them to an organization that would guarantee the management of waste oils in consistence with legal regulations.

If the regeneration of waste oil is impossible due to the contamination degree, the oil should be subjected to other recovery processes. If regeneration or other recovery processes cannot be applied, it can be disposed of according to regulations.

The Act also provides a ban on mixing waste oil with other hazardous substances. The primary assumption of the act regarding the obligations of manufacturers in the field of some waste management, product fee, and deposit fee is to impose on manufacturers of lubricating oils an obligation to apply recovery, especially recycling (regeneration) of waste produced from these products. In order to make it possible, manufacturers are provided with the possibility to enter into cooperation with organizations which, according to the rules, are obliged to take over the actions connected with waste oils recovery and recycling.

3. Regeneration of waste oil

According to the rules, the regeneration of waste oil is the basic and the most rational way to recover waste oil.

Used oils as an energy source, as an alternative to crude oil in production of base oils, reduce consumption of fossil fuels. 1 ton of crude oil provides

approximately 0.15 Mg of base oils, whereas 1 ton of used oil provides approximately – 0 Mg.

Waste oil should be first subjected to recovery through regeneration, understood as each process in which base oil can be manufactured by refining waste oil. These directives have been introduced, because the production of base oil by waste oils regeneration on modern equipment needs half as much energy than is needed for the production of base oils from crude oil.

If the regeneration of waste oil is not possible, it should undergo other recovery processes, so that it can be disposed of properly.

3.1. Re-refining of waste oils on the example of EUROBAC Company

The re-refining system in Trzebinia of Eurobac sp. z o.o. Company is one of the systems that implement the requirement of waste oil recovery and recycling. An organizational scheme of the company is presented in Fig. 2.

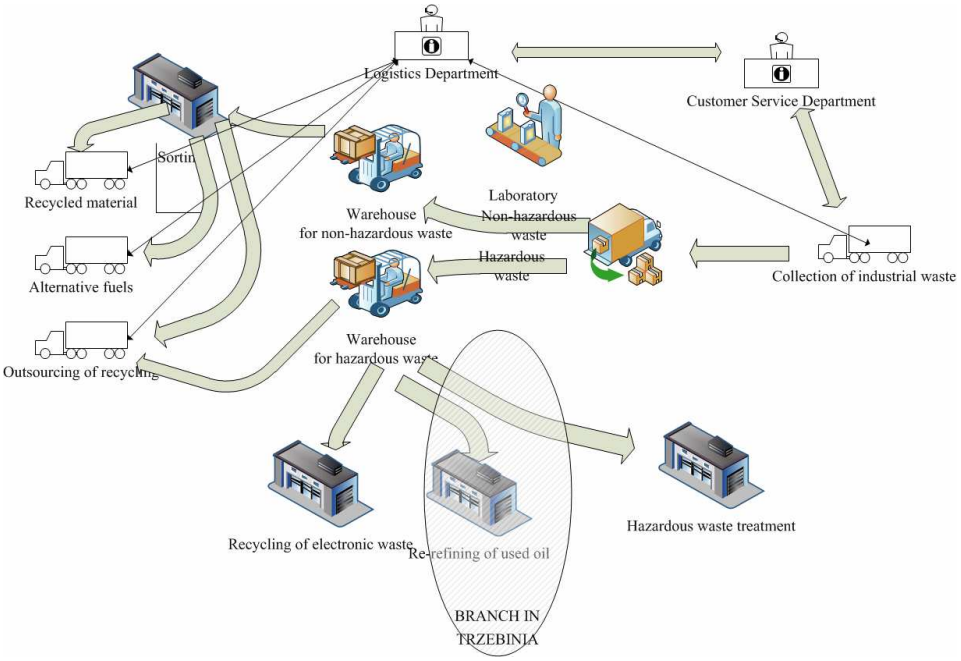

Fig. 2. General organisation of a hazardous waste recycling company

The distillation of used oil (Fig. 3) [1, 4, 5, 6] includes three steps. In the first step, the used oil is subjected to initial vacuum distillation (to 150ºC) to remove contamination and the most volatile fractions.

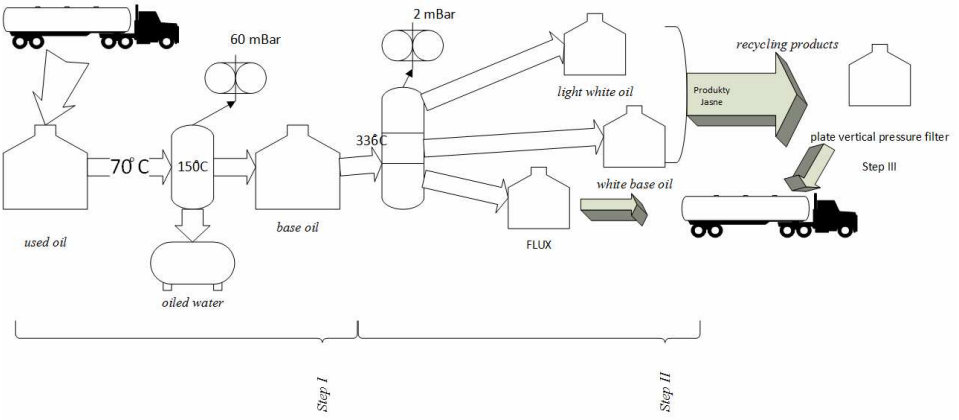

Fig. 3. Scheme of re-refining process of used oils

Next, the stream of dried oil enters the second step (Fig. 4.), and it is transferred to a distillation column (up to 336ºC), where it is separated into fractions. In the second step, the column operates under high vacuum (up to 2mBar P1V101), and it has a high separation efficiency, due to its structural packet filling. The obtained lateral fractions are directed to further refining treatment in the third step, which involves the filtration of the base fraction on plate filters.

3.2. Description of technological process of the second step

The most important re-refining step is Step II [8]. Before treatment in vacuum evaporator E-101, volatile substances and water are removed from the waste oil in the node for drying. This predistillation process is very important for the vacuum step, which is carried out under absolute pressure, below 1 kPa. The diffused material is transported to a thin layer evaporator E-101 at boiling temperature. The evaporator is heated in a controlled manner, which is important for the effective use of the evaporator's variable temperature hot plate whose dimensions limit the efficiency. For this purpose the spray is heated from 60°C to 120°C by the heat of boiling excess E-103 and up to 200°C by the heat of condensing oil steam E-102. The spray is brought on the lower sieve plate of the thin layer evaporator E-101 where there is a guide wheel producing rising streams. Thanks to this, the liquid fills tubes uniformly, while co-mixing the fed oil. The rising stream is heated by a thermophore.

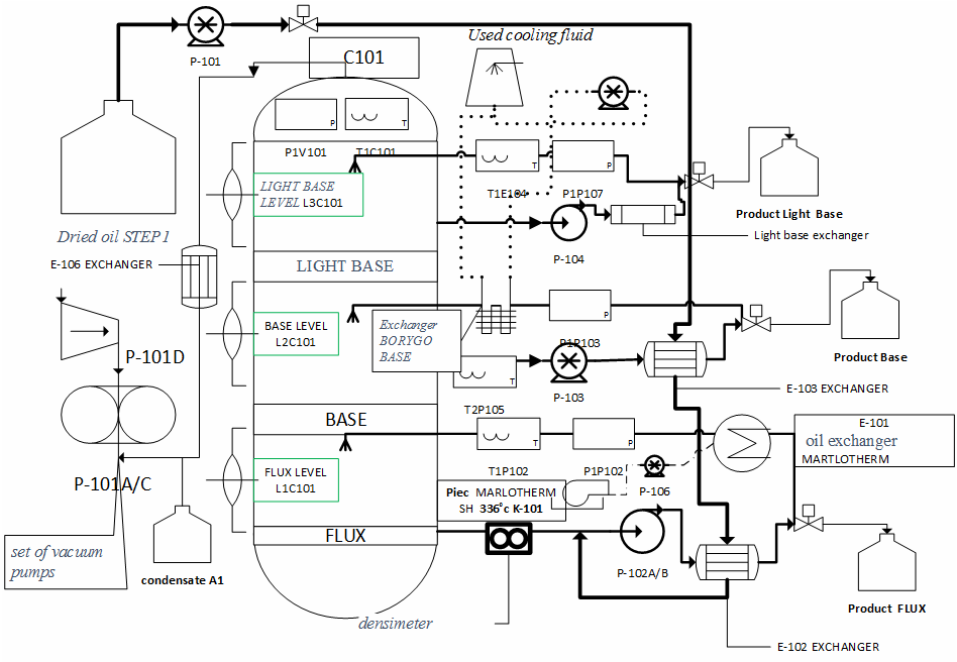

Fig.4. Scheme of Step II

MARLOTHERM SH (336ºC) flows in the inter-tube space with divisions, the thermophore is pumped downwards in the direction opposite to the oil film. Thanks to the fact that more volatile fractions are evaporated from the oil film, concentrations of heavy fractions occur, due to which the temperature in the upper part of the evaporator is different than the lower and bottom parts of the evaporator, because it contains a new colder load of oil. The thermophore circulation, apart from evaporator E-101, also includes thermophore pump P-106, and thermophore heater K-101. The fumes produced during burning of fuel oil are forced through a fan into a burner and expansion tank. In evaporator E-101, a liquid film is pumped upward by circulating pumps P-102A or P-102B together with evaporated oil vapours. The boiling excess of the steam-liquid mixture is separated in the lower part of demister separator C-101. Vapours go up and a separate distillation excess is pumped out and recycled. In order to achieve a better result of the demister's lower part separation C-101, it is condensed downward by a small quantity of the distillate. In this way, the demister is moisturized by a clean liquid that will partly evaporate due to contact with steams that have been evaporated in a balance with substances hard to boil at a higher temperature on the bottom of the evaporator. The separated liquid flowing down from the demister will be carried away to a separate boiling excess. The boiling excess from the bottom C-101 is transported through pump

P-102 A or P-102B and radiator E-102 to the flux product tank. The residue with a temperature of 302ºC will be cooled down to 128ºC with the simultaneous heating of the upcoming spray from a temperature of 60ºC up to 112ºC. Purified oil vapours are carried from the demister through a bubble cap plate where vapour goes to the middle part of column C-101. In the middle part of column C-101, the oil vapours are condensed on a circulating colder oil flowing down a highly efficient structural packing. The distillate, after passing through the packing, is heated, and oil vapour is partly condensed, due to which there is more fluid in the middle part. The oil condensate is pumped out by pump P103 by heat exchanger E-103, where it shares its heat with the spray and goes back to the column nozzle. The excess of the condensed distillate, depending on the level, is carried away by a BAZA product tank. The assumed temperature of distillate ranges from 150°C to 190°C, depending on utilization of the falling heat for heating the spray. Uncondensed vapour in the middle part of column C-101 is transferred through the structural packing onto the second a bubble cap plate, and, upon entering into contact with cold oil, it condenses all components that undergo condensing at 35°C. The condensate from the upper part of the column contains products of a lower boiling temperature than those from the middle part of the column. In order to enable their self- treatment, they are stored separately in product NAFTY tank. After going through a drop separator from the head of column C-101, inert gases are supplied to a vacuum pump with a water ring-indirect cooling (P-101A/C and P-101D). A vacuum pump consists of booster P-101C, which condenses the soaked gases. The temperature of gases going out of the booster is approximately 50°C as they are cooled in a glycol radiator E-106. Passage of the gases through a cooler condenses most of uncondensed gases which go down to degassing tank A-1.

The condensates contain the lightest fractions such as diesel fractions of toluene. The condensates undergo self-treatment. The remaining gases require additional firing, because they were absorbed into the liquid phase while going through a water ring of the vacuum pump. Water is pumped out as technological sewage and transported to a specialist recycling system. The vacuum system is able to produce absolute pressure up to 2 mbars, which causes a reduction of the spray distillation temperature.

Summary

The main advantage of the process of waste oil re-refining and regeneration are cost efficiency and ecological benefits. The production cost of one kg of full quality base oil from regenerated waste oil is lower by approximately 50% than the production cost of 1 kg of base oil from crude oil. Thanks to re-refining and regeneration of waste oils, there is no need to store and utilize them, which contributes positively to environment protection and reduces oil extraction. The

described system is consistent with the requirements of the recovery and recycling of waste oil to be met by manufacturers and importers of lubricating oils.

In the next article on the subject of the analysed system, the authors are going to describe the results of studies regarding the following:

- Problems connected with the system operation,
- Improvements in the quality of products, and
- Operation and maintenance costs reduction.

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Ekonomiczne i środowiskowe aspekty przetwarzania przepracowanych olejów użytkowych – część I

Słowa kluczowe

Ustawa o odpadach, regeneracja olejów odpadowych, destylacja próżniowa.

Streszczenie

W artykule przedstawiono uwarunkowania prawne regulujące recykling olejów odpadowych, omówiono schemat organizacyjny przedsiębiorstwa Eurobac sp. z o.o. oraz proces regeneracji olejów odpadowych. Zaprezentowana w artykule instalacja została zmodyfikowana poprzez opracowanie nowego oryginalnego oprogramowania własnego autorstwa sterującego całą rafinerią, w tym: Destylacji próżniowej do 150ºC (Etap pierwszy), Destylacji próżniowej do 350ºC (Etap drugi) oraz filtracja gotowego produktu na filtrach płytowych (Etap trzeci). Jest to pierwsza z cyklu planowanych publikacji dotyczących rerafinacji olejów odpadowych.