Eksergi
Chemical Engineering Journal
Vol 22, No. 1. 2025

ISSN: 1410-394X
e-ISSN: 2460-8203

Used Lubricating Oil Treatment and Reuse for Sustainable Production Processes in Cement Industry

Erna Lestianingrum[a], Lisendra Marbelia[b*]

[a] *PT Indocement Tunggal Prakarsa, Palimanan, Cirebon, 45161, Indonesia*

[b] *Chemical Engineering Department, Faculty of Engineering, Universitas Gadjah Mada, Yogyakarta, 55281, Indonesia*

Article history :

Submitted 6 June 2024
Revision 8 October 2024
Accepted 9 October 2024
Online 5 December 2024

ABSTRACT: Used lubricating oil is one type of hazardous waste produced in the chemical industry, including the cement industry. PT. ITP Unit Palimanan has obtained a permit to process hazardous waste in the form of used lubricant oil since February 21, 2023. Therefore, starting from March 2023, PT. ITP Unit Palimanan has been utilizing used lubricant oil for open chain lubrication. The used lubricant oil, which is dark in color and contains a high number of particles, is reprocessed through a filtration process before being used. In this process, the contaminating particles are reduced, and the used lubricant oil can be reused as lubrication material for open chains within PT. ITP Unit Palimanan itself. In 2019-2021, the average total generation of used lubricant oil was around 125 tons per year. Of this amount, approximately 90% was suitable for reuse as it contained metal and water levels below the threshold limits. Through this reuse process, the substitution of lubricant oil for open chain equipment can be reduced by 95.5%, equivalent to Rp 1,514,556,289 per year or Rp 4,207,101 per day. Besides the cost savings, PT. ITP Unit Palimanan can significantly reduce the burden of used lubricant oil waste on the environment through this innovation.

Keywords: hazardous and toxic waste; lubricating oil; reuse

1. Introduction

Lubricating oil is a complex mixture composed of hydrocarbon compounds with varying molecular weights (Aljabiri, 2018), fundamentally consisting of base oil and various additives (Anisuzzaman et al., 2021). Over time, lubricating oil undergoes degradation, oxidation, and contamination, typically characterized by darker coloration, cloudiness, and increased levels of solids and water (Anisuzzaman et al., 2021). Asia is the largest consumer of lubricating oil globally (Silva et al., 2022a). Consequently, various efforts to recycle and reuse used lubricating oil are necessary (Abdulkareem et al., 2014; Pinheiro et al., 2021; Widayati & Achmad, 2008), to prevent negative environmental impacts, such as groundwater, surface water, and soil contamination (Hassanain et al., 2017).

The reuse of used lubricating oil is generally categorized into three methods: incineration for use as fuel, reprocessing, and re-refining to recover base oil (Anisuzzaman et al., 2021). Recent studies have also explored approaches related to circular economy and Life Cycle Assessment for lubricating oil usage (Hassanain et al., 2017; Pinheiro et al., 2021; Silva et al., 2022a). These studies indicate that reprocessing and re-refining are better alternatives compared to using lubricating oil as an alternative fuel. The re-refining process can involve both chemical and physical methods, including acid treatment, distillation, extraction, filtration, and adsorption (Anisuzzaman et al., 2021). Filtration and adsorption are widely employed to remove impurities and heavy metals (Aini & Supratikno, 2018; Wahyu et al., 2017).

In the cement industry, the use of lubricating oil faces unique challenges due to the industrial environment being heavily laden with solid particles and dust, which can easily contaminate the lubricating oil used in equipment and machinery (Elehinafe et al., 2022; Sheikh et al., 2011). Consequently, the consumption of lubricating oil and the production of used lubricating oil in the cement industry are relatively high (Che Jamin & Zalina Mahmood, 2015). Additionally, as used lubricating oil is categorized as hazardous waste, its management must be carried out properly and in accordance with applicable regulations (Elehinafe et al., 2022; Silva et al., 2022a). The objective of this study is to examine and evaluate the reuse of used lubricating oil in the cement industry, specifically at PT ITP Palimanan Unit. This begins with administrative processes, where the procedures for managing hazardous and toxic waste materials are outlined in Permen LHK No. 6 of 2021, Article 121, Paragraph (1), Section b2. According to this regulation, used lubricating oil can be reused as a lubricant for maintenance purposes. The study further involves data collection through mass balance analysis, reprocessing,

* Corresponding author
Email address: lisendra.m@ugm.ac.id

characterization of used lubricating oil, and calculations of the potential cost savings achieved.

2. Materials and Methods

2.1. Mass Balance Data Collection for Lubricating Oil

The mass balance data for lubricating oil usage was collected over three years: 2019, 2020, and 2021. The recorded usage includes lubricating oil for activities involving mobile equipment/heavy machinery as well as production machinery.

2.2. Management of Used Lubricating Oil

The management process for used lubricating oil begins with the collection of used lubricating oil waste (B105d) at the hazardous waste temporary storage facilities (TPS B3), with TPS 1 designated for production machinery maintenance and TPS 3 for heavy equipment/mobile vehicle maintenance. The physical condition of the used lubricating oil stored in drums is inspected, and the oil is sorted to identify those suitable for reuse. A reuse utilization report (reuse documentation) is prepared as evidence of hazardous waste removal for utilization activities. Reusable used lubricating oil is transported to the lubrication site for open-chain equipment, while non-reusable waste is managed separately: contaminated rags (B110d) are utilized as alternative fuel, and contaminated metal and other waste (B108d) are handed over to third-party waste processors. At the lubrication site, reusable used lubricating oil is transferred into a tank equipped with filters to remove dirt and residues. The filtered lubricating oil is then transferred to the main storage tank/reservoir located above the open-chain equipment. From the main reservoir, the lubricating oil is supplied to the open-chain equipment using gravity with specific flow controls. The used lubricating oil is utilized for lubrication of open-chain equipment within the permissible limits. If dirt or residue is detected during the reuse process, it will be collected and handed over to the hazardous waste TPS management.

2.3. Characterization of Lubricating Oil

To compare the physical properties of used and new lubricating oil, characterization was conducted. This process includes analyzing the water content and the levels of other metal contaminants.

2.4. Cost Savings Calculation

The cost savings calculation was based on the recorded mass balance of lubricating oil, determining how much new lubricating oil needed to be purchased versus how much used lubricating oil could be reused.

3. Results and Discussion

The study on the reuse of used lubricating oil at PT ITP Palimanan Unit was conducted in several stages, beginning with the submission of permits in accordance with Permen LHK No. 6 of 2021, Article 121, Paragraph (1), Section b2. This regulation allows the reuse of used lubricating oil for lubrication purposes in maintenance activities. PT ITP Palimanan Unit received its permit for hazardous waste management of used lubricating oil on February 21, 2023. Consequently, starting in March 2023, PT ITP Palimanan Unit began utilizing used lubricating oil for open-chain lubrication.

In addition to the permitting process, this study also included a detailed analysis of the mass balance and characterization of used lubricating oil. At the end of the study, a cost calculation was performed to evaluate the potential savings from the used lubricating oil reuse program.

3.1. Lubricating Oil Usage Data

Table 1 and Figure 1 illustrate the total lubricating oil requirements. The usage is divided into two main categories: mobile vehicles and production machinery.

.

Table 1. Lubricating Oil Requirements

No.	Activity	Quantity (tons/year)	Cost (Rp/year)
	Mobile Vehicles / Heavy Equipment		
1	Hydraulic Oil	36,148	1.253.706.311
2	Transmission Oil	21,708	799.095.600
3	Final Drive & Differential Oil	8,910	311.366.000
4	Engine Oil	26,730	990.165.000
5	Compressor Oil	0,368	165.130.559
6	Steering Oil	0,846	25.080.000
7	Brake Oil	0,002	283.5
	Total 1	94,712	3.544.826.970
	Production Machinery		
8	Gearbox Oil	65,572	3.384.762.025
9	Open Chain Oil	117,806	1.585.994.880
	Total 2	183,378	4.970.756.905
	Grand Total	278,090	8.515.583.875

As seen in Table 1, the highest consumption of lubricating oil is for production machinery maintenance, particularly for open-chain lubrication, amounting to 117,806 tons per year. Consequently, open-chain maintenance has become a primary target for the used lubricating oil reuse program.

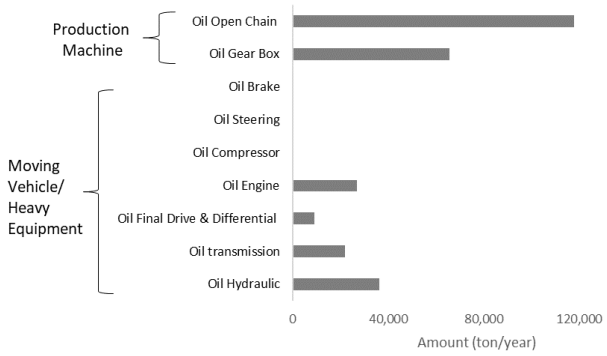

Figure 1. Lubricating Oil Usage at PT ITP Palimanan Unit

ISSN: 1410-394X
e-ISSN: 2460-8203

3.2. Characterization of Used Lubricating Oil

Figure 2 illustrates the physical condition of used lubricating oil obtained from maintenance activities on production machinery and heavy equipment. As shown in Figure 2, new lubricating oil has a clear appearance. After use, the oil changes color: for production machinery maintenance, it turns light brown (Figure 2a), whereas for heavy equipment maintenance, it becomes dark brown or black (Figure 2b).

Figure 2. Physical condition of used lubricating oil from maintenance activities: (a) production machinery and (b) heavy equipment

In addition to color, another important indicator for lubricating oil is viscosity (Aljabiri, 2018; Wahyuni Santi Rahardiningrum et al., 2016). According to the SAE (Society of Automotive Engineers), lubricating oil viscosity is categorized into three levels: thin, medium, and thick. Low-viscosity or thin oil flows easily, providing effective protection for engine components at low temperatures. Conversely, high-viscosity or thick oil performs better in high-temperature conditions.

Table 2. Comparison of Physical Conditions

Parameter	Used Oil from Production Machinery	Used Oil from Heavy Equipment
Color	Light brown	Dark brown/Black
Viscosity	Thin to Medium	Medium to Thick

Table 2 indicates an increase in viscosity after usage. However, this remains within acceptable criteria, where medium and thick oil can still be used for open-chain lubrication in production machinery.

Laboratory analysis was also conducted on the used lubricating oil, with results presented in Table 3. As shown, the heavy metal content values are below the threshold limit values (TLV). For moisture content, when compared with references for re-refined base oil, the moisture levels in the used lubricating oil are acceptable, remaining below 0,5%. Similarly, the metal content is below 10 ppm (Abdulkareem et al., 2014). Therefore, it can be concluded that the used lubricating oil is suitable for reuse in lubrication applications. Additionally, there is potential for alternative use as a fuel due to its relatively high calorific value.

Table 3. Laboratory Analysis Results

Parameter	Used Oil from Production Machinery	Used Oil from Heavy Equipment	Threshold Limit Value (TLV)
Moisture (%)	0,07	0,19	-
Heat Content (cal/gr)	10685	10703	> 2500
Arsenic (ppm)	0,0	0,0	≤ 5
Cadmium (ppm)	0,1	0,0	≤ 2
Chromium (ppm)	3,0	3,7	≤ 1500
Lead (ppm)	0,0	0,0	≤ 100
Mercury (ppm)	0,2	0,0	≤ 1,2

3.3. Reuse of Used Lubricating Oil

Figure 3 illustrates the flow diagram for the internal management of used lubricating oil hazardous waste (B3). The initial demand for new lubricating oil is as shown in Table 1: 94,712 tons/year for mobile vehicles and 183,378 tons/year for production machinery.

The quantities of used lubricating oil generated in 2019, 2020, and 2021 were 131, 127, and 116 tons/year, respectively. On average, this amounts to 125 tons/year or approximately 10,42 tons/month. As outlined in Subsection 2.2, the used lubricating oil is collected at the B3 waste temporary storage facility (TPS) and sorted based on its suitability for reuse.

Based on field observations, approximately 10% of the used lubricating oil is unsuitable for reuse due to contamination with water and other residues. However, 90% of the used oil, equivalent to 112.5 tons/year or 9.38 tons/month, can be reused for open-chain maintenance.

Figure 4 depicts used lubricating oil from production machinery maintenance stored in the TPS 1 LB3 facility. Following the process outlined in Figure 3 and the method described in Subsection 2.2, the sorted, reusable used lubricating oil is transferred to the utilization site for open-chain lubrication.

Figure 5 shows the utilization site for used lubricating oil in open-chain lubrication. At this location, the used oil is stored in a tank equipped with filters and then transferred to a main reservoir tank positioned above the system. The used lubricating oil is subsequently distributed to the open-chain equipment using gravity, as needed and with specific flow controls.

Figure 4. Used lubricating oil stored in TPS 1 LB3.

Figure 5. Utilization of used lubricating oil in open-chain equipment.

From Figures 3-5, the efforts to reuse used lubricating oil at PT ITP Palimanan Unit are clearly demonstrated. Compared to methods of reusing used lubricating oil from existing references (Abdulkareem et al., 2014; Aljabiri, 2018; Hassanain et al., 2017; Pinheiro et al., 2021), the reuse process at PT ITP Palimanan Unit remains relatively simple. The used lubricating oil undergoes basic filtration before reuse. Nonetheless, this innovation represents a significant initial step. For long-term sustainability, further in-depth research is necessary.

In addition to the reuse of used lubricating oil, similar efforts have been applied to other types of waste oil (Ilcham et al., 2013; Mannu et al., 2020; Restu Dewati et al., 2013; Yu et al., 2012).

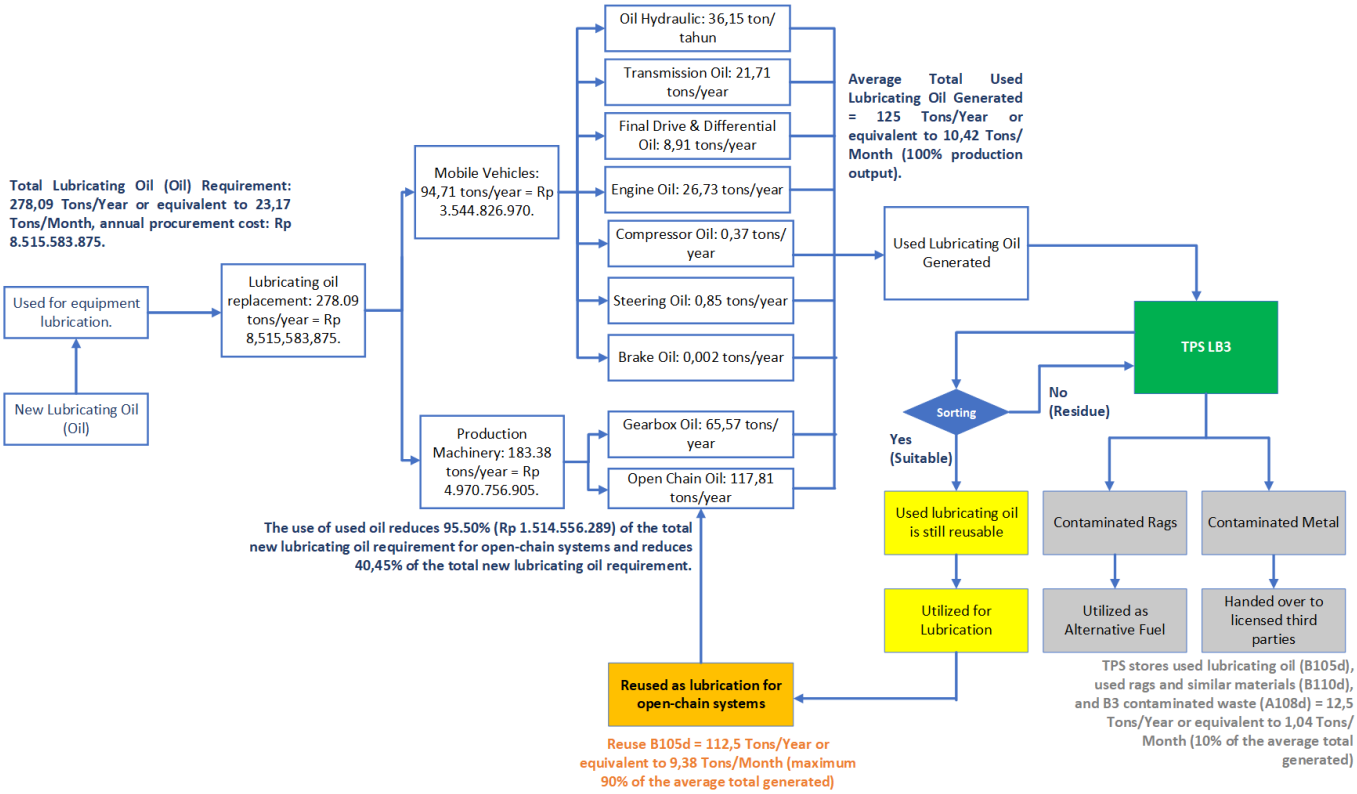

Figure 3. Internal hazardous waste (B3) management flow diagram for used lubricating oil.

ISSN: 1410-394X
e-ISSN: 2460-8203

Table 4. Utilization of Used Lubricating Oil and Its References (Belchinskaya et al., 2021; Moses et al., 2023; Silva et al., 2022b; Widodo et al., 2020)

Category	Utilization
Heating	Can be used in boilers, bakeries, and domestic stove fuels.
Construction	Used as a binder for asphalt in road construction.
Fuel	Through thermal cracking and distillation, it can produce diesel, gasoline, and kerosene.
Preservation	Suitable for wood preservation through impregnation.
Filtration (for hydraulic and gear oil)	By removing impurities through filtration, used lubricating oil can be directly reused as hydraulic and gear oil.

Table 4 highlights various references on the utilization of used lubricating oil. The current study adopts the last method, where used lubricating oil is filtered and directly reused for open-chain equipment. Other potential applications could be explored in the future to expand the scope of used lubricating oil utilization (Moses et al., 2023).

3.4. Cost Savings & Implications

Table 5 summarizes the lubricant requirements for open-chain equipment at PT ITP Palimanan Unit and the associated cost savings achieved through the reuse of used lubricating oil. The total lubricant requirement is 117,8 tons per year, of which 112,5 tons (95,5%) can be met through reuse. This reuse activity results in an estimated annual cost reduction of Rp 1.514.556.289.

The cost savings presented above indicate the potential benefits that PT ITP Palimanan Unit could achieve within the year. However, further research is necessary to obtain long-term insights into the sustainability of the program. Studies utilizing life cycle assessment (LCA) suggest that reusing used lubricating oil is one of the best alternatives for mitigating environmental impacts (Botas et al., 2017). Two critical factors need to be considered concerning environmental impact: mass flow and economic value (Botas et al., 2017). By exploring alternative processes for used lubricating oil treatment, techno-economic evaluations can be performed. More detailed studies on techno-economic analysis are essential for future implementation (Moses et al., 2023).

4. Conclusions

The reuse program for used lubricating oil at PT ITP Palimanan Unit was systematically conducted, starting with obtaining permits from the Ministry of Environment and Forestry, followed by data collection, characterization, management arrangements, and cost-saving calculations. From the mass balance data, it was identified that open-chain lubrication activities consume the largest amount of lubricating oil. Physical observations and the characterization of water and metal content revealed that approximately 90% of the used lubricating oil has values below the threshold limits, making it suitable for reuse. The used lubricating oil was processed through filtration and reused for open-chain equipment lubrication. The data show that this reuse program can substitute 95,5% of the new lubricating oil required for open-chain lubrication, equivalent to an annual cost saving of Rp 1.514.556.289 or Rp 4.207.101 per day. For the sustainability of this program, further research is needed to assess its long-term impacts on processes, economic viability, and environmental effects.

Table 5. Lubricant Requirements for Open Chain Equipment and Potential Savings

No	Open Chain Equipment	Lubrication Requirement Estimate			
		Unit	Per Year	Per Month	Per Day
1	Limestone reclaimer	Ton	52,49	4,37	0,146
2	Trass reclaimer	Ton	23,33	1,94	0,065
3	Apron feeder limestone crusher	Ton	3,89	0,32	0,011
4	Apron feeder additive crusher	Ton	0,19	0,02	0,001
5	Clinker conveyor	Ton	35,96	3,00	0,100
6	Apron feeder dozing raw material	Ton	1,94	0,16	0,005
	Total Lubricant Requirements	Ton	117,8	9,82	0,327
	Total Procurement Budget	Rp	1.585.994.880	132.166.240	4.405.541
	Used Lubricating Oil Substitution	Ton	112,5	9,375	0,3125
	Substitution Percentage	%	95,50	95,50	95,50
	Estimated Cost Reduction	Rp	1.514.556.289	126.213.024	4.207.101

Acknowledgments

This study was supported through a collaboration between PT ITP Palimanan Unit and the Department of Chemical Engineering, Universitas Gadjah Mada.

Statement

During the preparation of this work the authors used ChatGPT 3.5 in order to improve English language and proofread the text. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

CRediT authorship contribution statement

Erna Listianingrum: Writing – review & editing, Visualization, Validation, Resources, Investigation, Formal analysis, Conceptualization. **Lisendra Marbelia:** Writing – original draft, review & editing, Visualization, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

References

Abdulkareem, A. S., Afolabi, A. S., Ahanonu, S. O., & Mokrani, T. (2014). Effect of treatment methods on used lubricating oil for recycling purposes. *Energy Sources, Part A: Recovery, Utilization and Environmental Effects*, *36*(9), 966–973. https://doi.org/10.1080/15567036.2010.549920

Aini, S., & Supratikno, S. (2018). Application of five isoterm adsorption equilibrium models on adsorption of Chrom VI metal ion by zeolite. *Eksergi, 15*(2), 48–53. https://doi.org/10.31315/E.V15I2.2385

Aljabiri, N. A. (2018). Comparative study of recycling used lubricating oils using various methods. *Journal of Scientific and Engineering Research, 5*(9), 168–177. http://www.jsaer.com

Anisuzzaman, S. M., Jumaidi, M. H., & Nasir, N. N. M. (2021). Used lubricating oil recovery process and treatment methods: A review. *IOP Conference Series: Materials Science and Engineering*, *1195*(1), 012031. https://doi.org/10.1088/1757-899x/1195/1/012031

Belchinskaya, L., Zhuzhukin, K. V., Ishchenko, T., & Platonov, A. (2021). Impregnation of wood with waste engine oil to increase water-and bio-resistance. *Forests*, *12*(12), Article 1762. https://doi.org/10.3390/f12121762

Botas, J. A., Moreno, J., Espada, J. J., Serrano, D. P., & Dufour, J. (2017). Recycling of used lubricating oil: Evaluation of environmental and energy performance by LCA. *Resources, Conservation and Recycling, 125*, 315–323. https://doi.org/10.1016/j.resconrec.2017.07.010

Che Jamin, N., & Zalina Mahmood, N. (2015). Hazardous waste management in Malaysia: A case study on cement manufacturing. *Procedia Engineering*, 118, 35–41. https://doi.org/10.13140/RG.2.1.3646.2808

Elehinafe, F. B., Ezekiel, S. N., Okedere, O. B., & Odunlami, O. O. (2022). Cement industry–Associated emissions, environmental issues and measures for the control of the emissions. *Mechanical Engineering for Society and Industry*, *2*(1), 17–25. https://doi.org/10.31603/mesi.5622

Hassanain, E. M., Yacout, D. M. M., Metwally, M. A., & Hassouna, M. S. (2017). Life cycle assessment of waste strategies for used lubricating oil. *International Journal of Life Cycle Assessment*, *22*(8), 1232–1240. https://doi.org/10.1007/s11367-016-1255-x

Ilcham, A., Tri Retno, D., Syahputra, A., & Novie Aprianto, P. S. T. K. M. (2013). Pengaruh oil sludge Pertamina Surabaya terhadap kuat tekan keramik tradisional. *Eksergi*, *11*(1), 7–11.

Mannu, A., Garroni, S., Porras, J. I., & Mele, A. (2020). Available technologies and materials for waste cooking oil recycling. *Processes*, *8*(3), Article 288. https://doi.org/10.3390/pr8030288

Moses, K. K., Aliyu, A., Hamza, A., & Mohammed-Dabo, I. A. (2023). Recycling of waste lubricating oil: A review of the recycling technologies with a focus on catalytic cracking, techno-economic and life cycle assessments. *Journal of Environmental Chemical Engineering*, *11*(6), Article 111273. https://doi.org/10.1016/j.jece.2023.111273

Pinheiro, C. T., Quina, M. J., & Gando-Ferreira, L. M. (2021). Management of waste lubricant oil in Europe: A circular economy approach. *Critical Reviews in Environmental Science and Technology*, *51*(18), 2015–2050. https://doi.org/10.1080/10643389.2020.1771887

Restu Dewati, P., Halim Purbohandono, A., & Budiman, A. (2013). Pre-treatment process of biodiesel production from waste cooking oil. *Eksergi*, *11*(1), 1–6.

Sheikh, A. M., Khashaba, M. I., & Ali, W. Y. (2011). Reducing the mechanical wear in a dusty environment (cement factory). *International Journal of Engineering & Technology*, *11*(6), 138–144. https://www.researchgate.net/publication/265999413

Silva, N. R., Rodrigues, T. O., Braga, T. E. N., Christoforo, A. L., & Silva, D. A. L. (2022a). Re-refining of lubricant oil used and contaminated (LOUC) or its combustion in cement plants? An exploratory study in Brazil based on the life cycle assessment and circularity indicators. *Sustainable Production and Consumption*, *33*, 360–371. https://doi.org/10.1016/j.spc.2022.07.017

Wahyu, L., Setyaningsih, N., Zahra, I., Asmira, N., Chairiza, F. W., & Kimia, J. T. (2017). Aktivasi dan aplikasi zeolit alam sebagai adsorben logam kromium dalam air limbah industri penyamakan kulit. *Eksergi*, *14*(1), 7–11. https://doi.org/10.31315/E.V14I1.2013

Widodo, S., Khoiruddin, K., Ariono, D., Subagjo, S., & Wenten, I. G. (2020). Re-refining of waste engine oil using ultrafiltration membrane. *Journal of Environmental Chemical Engineering*, *8*(3), Article 103789. https://doi.org/10.1016/j.jece.2020.103789

Yu, M., Ma, H., & Wang, Q. (2012). Research and recycling advancement of used oil in China and all over the world. *Procedia Environmental Sciences*, *16*, 239–243. https://doi.org/10.1016/j.proenv.2012.10.033