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Study of the environmental impact of refining used lubricant oils using Life-cycle Assessment methodology as strategy

Estudio del impacto ambiental de la refinación de aceites lubricantes Aplicando el Análisis de Ciclo de Vida

José Valencia Chavez[1], Carlos E. Diaz-Uribe[2], William Vallejo-Lozada[3]

[1]Magister en Ciencias Ambientales, Grupo de Investigación en Fotoquímica y Fotobiología Universidad del Atlántico. Barranquilla, Colombia.
[2]Doctor en Química, Grupo de Investigación en Fotoquímica y Fotobiología Universidad del Atlántico. Barranquilla, Colombia.
[3]Doctor en Ciencias Químicas, Grupo de Investigación en Fotoquímica y Fotobiología Universidad del Atlántico. Barranquilla, Colombia.
Corresponding author: williamvallejo@mail.uniatlantico.edu.co

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ABSTRACT

Used lubricating oil is an anthropogenic pollutant difficult to handle due to its toxicity and physical state. The re-refined process demanded less natural energy resources than non-refined option become it in a sustainable option to the recovery of used lubricating oil. In the present work, a Life Cycle Assessment (LCA) was carried out for the re-refining technology by thin layer distillation in a real process for using the OPENLCA software version 1.11 and the midpoint method of ReCiPe 2016 (H) V1.13. The inventory information was compiled from a real plant and, other part of the information was obtained in dialogue with experts in used oil treatment processes or consulted in specialized sources and extracted from the database Ecoinvent data 3.8. Results were obtained in 10 of the 12 impact categories under study and it was evident that the substitute process flow, to obtain lubricant base, positively impacts avoiding all the categories studied with values different from zero (results with negative values). The highest environmental impact was associated with the category of climate change with a value of 0.1232 kg CO_2-Eq. Furthermore, the most relevant impact to be avoided by the re-refining process is human toxicity with a value of -0.0265 kg 1,4-DCB-Eq. Finally, the re-refined process contributes to preventing environmental impacts in the categories of freshwater ecotoxicity, freshwater eutrophication, marine ecotoxicity, terrestrial ecotoxicity and human toxicity, the latter being the most relevant impact to be avoided.

Keywords: Life Cycle Assessment, Toxicity, used oils, re-refining

RESUMEN

Los aceites lubricantes usados son un contaminante antropogénico difícil de manejar debido a su toxicidad y estado físico. El proceso de refinado requiere menos recursos energéticos naturales que la metodología no refinada, lo que lo convierte en una opción sostenible para la recuperación de aceite lubricante usado. En el presente trabajo se realizó un Análisis de Ciclo de Vida (ACV) para la tecnología de refinación por destilación en capa fina en un proceso real utilizando el software OPENLCA versión 1.11 y el método de punto medio de ReCiPe 2016 (H) V1.13 . La información del inventario se compiló a partir de una planta real y, otra parte de la información se obtuvo en diálogo con expertos en procesos de tratamiento de aceite usado extraída de la base de datos Ecoinvent data 3.8. Los resultados se obtuvieron en 10 de las 12 categorías de impacto en estudio y se evidenció que el flujo de proceso sustitutivo, para obtener base lubricante, impacta positivamente evitando todas las categorías estudiadas con valores diferentes a cero (resultados con valores negativos). El mayor impacto ambiental se asoció a la categoría de cambio climático con un valor de 0,1232 kg CO_2-Eq. Además, el impacto más relevante que debe evitarse con el proceso de refinación es la toxicidad humana con un valor de -0,0265 kg de 1,4-DCB-Eq. Por último, el proceso de refinamiento contribuye a prevenir los impactos ambientales en las categorías de ecotoxicidad de agua dulce, eutrofización de agua dulce, ecotoxicidad marina, ecotoxicidad terrestre y toxicidad humana, siendo esta última el impacto más relevante a evitar.

Palabras Claves: Análisis de Ciclo de Vida, Toxicidad, aceites usados, refinación

1. INTRODUCTION

All the human activities yield secondary-products and wastes. Their appropriate manipulation and/or reuse of this compounds are one of the big challenge for the near future [1], [2]. The annual global production of waste is at least 4.5 billions tons and, among the main sources are the following sectors: (i) energy (e.g., waste from the production, processing, and combustion of fuels); (ii) industrial (used oils and chemicals, machinery and mechanisms); municipal (solid waste, sewage sludge, construction waste); wood and agricultural (e.g., sawmill waste, carpentry, agricultural waste) [3]. Exponential industrial and population growth in the last century, coupled with economic growth, has led to an increase in waste generation in recent years. Hazardous waste is a big environmental issue compared to non-hazardous waste as it poses a higher risk to the environment and human health [4], [5]. The field faced one challenge: they are improperly managed or disposed of due to their quantity, concentration, and physical, chemical, and infectious properties [6]. Hazardous waste includes any unwanted material in the form of a solid, semi-solid, liquid, or gas that could threaten humans and the environment if emitted, released, deposited, or discharged into the environment. These residues have one or more characteristics: flammability, corrosivity, reactivity, or toxicity [7]. The used lubricant oils (ULO) are considered a hazardous waste of mineral oils (not suitable for the use for which they were intended, or mixtures and emulsions of waste oil and water or hydrocarbons and water). According to the US Environmental Protection Agency (EPA), the ULO as a particular solid wastes, from certain common industrial or manufacturing processes are classified in the "F list designates" [8]. Reports indicate that more than 3.8 billions of gallons of ULO were commercially collected in 2017 [9].The ULO are danger to plant, animal, and aquatic life due to the fact that it contains dangerous pollutants such as additives, polycyclic aromatic hydrocarbons, and heavy metals (e.g., Pb^{2+}, Co^{2+}, As^{5+}, Cu^{2+}, Cr^{5+}, Cd^{2+}) [10]. ULO are nor easily removed from water by traditional methods [11]. There are different strategies for management ULO from water called re-refined techniques (e.g., flocculation [12], membrane technology [13], vacuum distillation [14], solvent extraction [15], acid clay [16]). The main purpose of them is recovering the ULO. Among all these techniques, the acid clay treatment is a traditional method to recycle ULO; the acid/clay process has the lowest cost and the highest environmental risk in comparison to the other regeneration technologies [17]. It is known that acid sludge produced after application of acid/clay treatment containing high concentration of heavy metals, which are dangerous to human beings, animal and environmental [18]. Lasts decades the Life cycle assessments (LCA) has demonstrated its efficiency as technique to study the impact of different process in the environmental [19]–[22]. Different authors reported that the re-refined process demanded less natural energy resources than non-refined option [23].

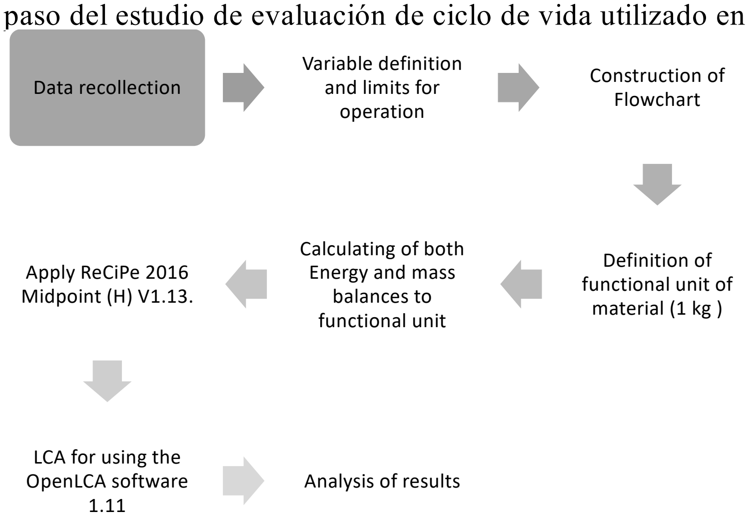
In Colombia exist two alternatives approved by legislation for using the waste lubricating oils: (i) energy recovery: this method has as starting point, the treated and untreated used lubricating oils, where it is possible to recover energy for use as an industrial fuel and as part of a mixture with other fuels (proportion less than 5%). This strategy is used in cement kilns, metallurgical, or power generation plants with efficient air emissions control systems [24]. (ii) The recycling of used lubricating oils through the re-refining process, with which lubricant bases are recovered for the formulation of new mineral oils and fuel derivatives for industrial use as established in NTC 5995 (Petroleum and by-products. Re-refined lubricant bases) [25]. These initiatives are part of the sustainable production and consumption policy that promotes, in most cases, the return of these products by consumers when they become waste when they become obsolete. In spite of re-refining of spent lubricating oils has been practiced with varying technical and commercial success for over the past 50 years [26]; in Colombia, the post-consumer plans for the management of waste oils have not been developed by the Ministry of Environment, mainly due to the few technological alternatives known and available in Colombia for their comprehensive treatment. Currently, Colombia have not a post-consumer management plan for waste from used lubricating and industrial oils and, although, there is a technical manual for the management of waste from mineral and synthetic lubricating oils in the country issued in 2014, there is no total guarantee that this hazardous waste will be collected, transported, transported, or transported treated and disposed of in an environmentally safe and effective manner. In this sense, to date the only document close to a post-consumer plan for used lubricating oils has been Resolution 1446 of 2005, which allows the use of used oils in mixtures as industrial fuels [24]. That is why there is a need to assess and to analyze production processes, taking into account the life cycle of the product, the waste generated and its possible impact on the environment. Proper management and reasonable use of resources play a central role both in developing an efficient economy and in maintaining those resources for future generations. Lubricating oil waste management is of immense importance for the sustainability of resources and improved economic, social, and environmental benefits. In the present work, a life cycle assessment was carried out for the re-refining technology by thin layer distillation in a real process for using the OPENLCA software version 1.11 and the midpoint method of ReCiPe 2016 (H) V1.13.

2. EXPERIMENTAL

2.1. Life Cycle Assessment of re-refining process

We carried out the LCA study according to the international standard ISO 14040 and ISO 14044 to quantify and analyze the environmental impacts of refining of used lubricating oil (ULO) by thin-film distillation technology. In the following paragraphs, we described each step of the LCA, focusing on the case study conducted. In this work we applied the descriptive model assay cradle to gate [27]. For thin-film technology re-refining technology: The recycling activity of used oils through re-refining comprises the moment from which the lubricating oil is collected at the generation sites and subsequently transported to the treatment plant in Cartagena (cradle), to the moment in which four types of alternative fuel by-products are generated (gate). We employed as a functional unit within the study 1 kg of used and collected mineral oil, which has already fulfilled its function as mineral oil according to its application and is potentially recoverable through technological processes of re-refining in order to obtain by-products other than the ULO with useful applications in the industrial sector.

Figure 1. The step-by-step of the Life-cycle Assessments study implemented in this work.
Figura 1. Paso a paso del estudio de evaluación de ciclo de vida utilizado en este trabajo



The industrial process studied in this work is a multifunctional process as is described by Dudak [28]. Different by-products are generated after process. In this substitution stage, the by-products derived from the re-refining process are substituted in a 1:1 ratio with other products of the same nature that are made with raw materials derived from virgin oil. The substitution was carried out in equivalences of mass, quality, and functionality. However, the lower price of these by-products is the main decision criterion for the consumption of products from re-refining. Table 1 lists the by-products substitutions implemented in the re-refining of used mineral oils. The life cycle impact assessment was determined at the midpoint and endpoint level ReCiPe 2016 (H) V1.13 [29]. Figure 1 shows the step-by-step of the LCA study implemented in this work.

Table 1. The by-products substitutions implemented in the re-refining of used mineral oils.

Tabla 1. Lista de subproductos implementados en la refinación de aceites minerales usados

By-product	By-product substitution
Lubricant base	Lubricant base re-refining petroleum
Bottom process base	Fuel oil base re-refining petroleum
Diesel base	Diesel re-refining petroleum
Light Naphtha base	Naphtha re-refining petroleum

2.2. LCA inventory

In the LCA study, we applied the effect evaluation for using the OpenLCA software 1.11 [30]. The Figure 2 shows the scheme of the re-refining process studied in this work. Table 2 lists the total emissions of the process after re-refining process shown in Figure 2.

Table 2. Total emissions of the process after re-refining process shown in Figure 2.

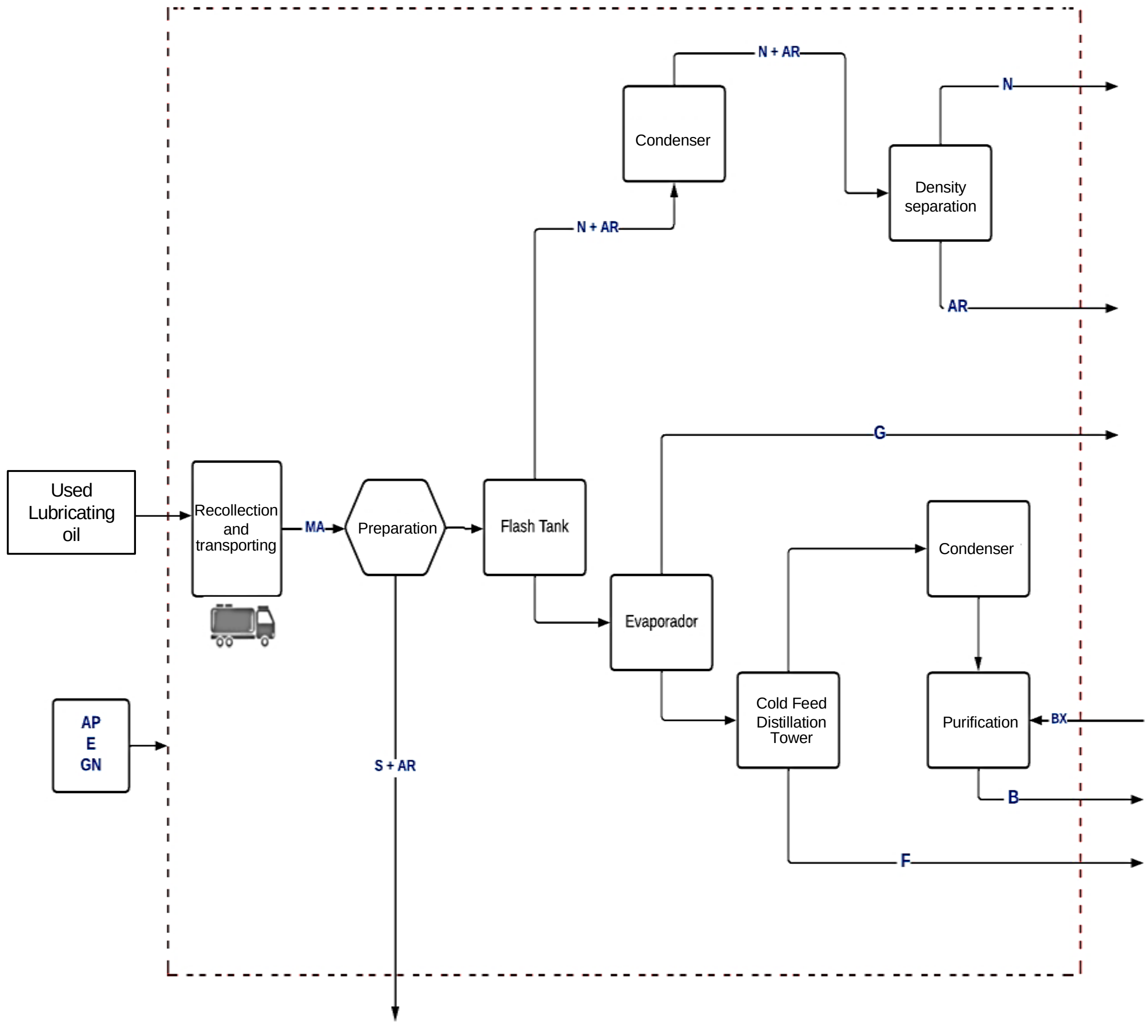
Tabla 2. Emisiones totales después del proceso de refinación que se muestran en la figura 2.

Physical emission	Description	Amount /unit
water	Biochemical oxygen demand (BOD)	2.88 x10^{-6} kg
water	Chemical oxygen demand (COD)	8.01 x10^{-6} kg
water	Total solids	1.1 x10^{-3} kg
water	Mass of oils	6.7 x10^{-3} kg
Air	Mass of SO_2	2.35 x10^{-6} kg
Air	Mass of NO_x	4.01 x10^{-7} kg
Air	Mass of CO_2	2.17 x10^{-1} kg

Figure 2. Scheme of the re-refining process studied in this work. MA: mass of used oil enters to the process (1 kg). S: mass of suspended solids filters (0.0015 kg). AR: mass of water enters to WWTP (0.011 kg). AP: volume of water in process (0.503 L). E: Electric Energy consumption (0.0356 kWh). GN: Volume of natural gas used for heating (0.1099 m^3). N: mass of Naphtha substitute (0.063 kg). B: mass of Lubricant base substitute (0.533 kg). F: mass of fuel oil substitute (0.229 kg). G: mass of Diesel substitute (0.155 kg). BX: mass of Clay used for base oil bleaching (0.0519 kg).

Figure 2. Esquema del proceso de refinación estudiado en este trabajo. MA: masa de aceite usado que entra en el proceso (1 kg). S: masa de sólidos suspendidos (0.0015 kg). AR: masa de agua

inhgresando al WWTP (0.011 kg). AP: volume de agua en el proceso (0.503 L). E: Consumo de Energía electrica (0.0356 kWh). GN: Volume de gas utilizado para el calentamiento (0.1099 m^3). N: masa de nafta sustituto (0.063 kg). B: mass de base de lubricante sustituto (0.533 kg). F: masa de combustible sustituto (0.229 kg). G: masa de Diesel sustituto (0.155 kg). BX: masa de arcilla utilizada para el blanqueo de aceites base (0.0519 kg).



3. RESULTS AND DISCUSSION

3.1. Life Cycle Assessment of re-refining process

The Table 3 shows the results of the 12 categories evaluated. Two impact indicators show an impact value equal to zero (fossil depletion and ozone depletion), which indicates the relationship of inputs and outputs of the inventory analysis according to the process studied does not contain materials that are related to these categories of environmental impact and therefore the reference flows evaluated show a value equal to zero. These impact categories will be omitted in subsequent analyses. The categories with non-zero values show that the geographical incidence of the life cycle of used oil until the end of life as a raw material for the thin film re-refining process takes place at regional and local scale. Positive values indicate the quantitative contribution of the reference flow to the generation of the assessed environmental impact. This value can be called the impact generated by the reference flow. The climate change indicator shows a value of 0.1232 kg CO2-Eq, this value is smaller than reported by Kanokkantapong et al., they reported a reported a life cycle study of different ULO management schemes to regenerate and energetically valorize 1 kg of ULO by regeneration processes (solvent extraction and acid clay treatment) and energy recovery (boilers and cement kiln); the global warming potential obtained to regenerate used oils by these authors for the solvent extraction process was around 0.3 kg-eq CO_2/kg [23]. In this same study, they showed that the scenario of energy recovery of the same amount of oil used in boilers and cement kilns, the results are much higher (3 kg-eq CO_2/kg in boilers and 3.1 kg-eq CO_2/kg respectively) than reported here in. The same trend is shown in work carried out in Brazil for the regeneration of 1 kg of used oil in oil recovery technology with dehydration and cracking, sulfonation and acid sludge, neutralization and distillation, dehydration and fractionation units of light oil [31]. They obtaining an impact of 96.3 kg-eq CO_2/kg, a value much higher than the results reported here in.

Table 3. Categories of the impacts in the re-refining process determined at the midpoint and endpoint level ReCiPe.
Tabla 3. Categorías de los impactos en el proceso de refinación determinados a nivel de punto medio y punto final ReCiPe.

Impact category	Reference unit	Re-refine	Re-refine substitute ULO	Contribution to reduce impact
Climate change	kg CO_2-eq	$1.23x10^{-1}$	$-4.83x10^{-1}$	$-4.83x10^{-1}$
Depletion of fossil	kg oil-eq	0	0	0
Water eco-toxicity	kg 1,4-DCB-eq	$-5.36x10^{-5}$	$-5.40x10^{-5}$	$-5.40x10^{-5}$
Water eutrophication	kg P-eq	$-1.25x10^{-6}$	$-1.30x10^{-6}$	$-1.30x10^{-6}$
Human toxicity	kg 1,4-DCB-eq	$-2.65x10^{-2}$	$-2.65x10^{-2}$	$-2.65x10^{-2}$
Marine eco-toxicity	kg 1,4-DB-eq	$-5.97x10^{-4}$	$-5.49x10^{-4}$	$-5.49x10^{-4}$
Marine eutrophication	kg N-eq	$1.73x10^{-5}$	$-3.58x10^{-5}$	$-3.58x10^{-5}$
Depletion of Ozone	kg CFC-11-eq	0	0	0
Photochemical oxidant generation	kg NMVOC-eq	$-5.35x10^{-4}$	$-8.39x10^{-4}$	$-8.39x10^{-4}$
Land acidification	kg SO_2-eq	$9.35x10^{-5}$	$-1.44x10^{-3}$	$-1.44x10^{-3}$
Land eco-toxicity	kg 1,4-DCB-eq	$-4.83x10^{-5}$	$-4.48x10^{-5}$	$-4.48x10^{-5}$
Depletion of water	m^3 water-eq	$-9.34x10^{-4}$	$-1.1x10^{-3}$	$-1.1x10^{-3}$

The negative numbers in the Table 3 indicate a net benefit from the waste management process analyzed, as the overall impact of waste treatment is more than offset by the avoided impact of the processes substituted with the co-products. The most relevant impact to be avoided by the re-refining process is human toxicity with a value of -0.0265 kg 1,4-DCB-Eq, resulting from water depletion, marine ecotoxicity, freshwater ecotoxicity, terrestrial ecotoxicity and freshwater eutrophication, which also yielded negative values. The toxicity value obtained is mostly related to the prevention of emissions from the production and use of fossil fuels, and this is reflected in Figures 2 and 3 where substitute flows for the production of lubricant-based, naphtha, diesel and fuel oil contribute positively to avoiding impacts in the category where their result is significant. Furthermore, avoiding impacts such as terrestrial ecotoxicity by the re-refining method is very significant since studies reveal that when the oil comes into contact with the soil, the portion that remains in it undergoes slow volatilization due to low vapor pressures (<0.001 mm Hg a 25 C), slow hydrolysis and/or microbial degradation [32]. Furthermore, this pollution induces substantial changes in living organisms, mainly those involved in the nitrogen cycle, since it fills the pores between the particles, preventing access to oxygen, inducing a significant number of anaerobic zones and, therefore, also the metabolic activity of anaerobic microorganisms. This process prevents plants from absorbing the polycyclic aromatic hydrocarbons present in the soil, especially the low molecular weight molecules, which move quickly to the tissues on the surface of the tissue [33].

The high management costs for the disposal of ULO leads to the illegal dumping of the ULO into bodies of water. The re-refining process, as in soil, prevents this hazardous waste from being dumped into bodies of water, endangering marine life causing the death of seabirds due to hypothermia. Besides, used mineral oils manifest a hydrophobic nature by inhibiting the dissolution of oxygen and increasing the chemical oxygen demand in the water [34].

Table 3 shows that the flow associated with the lubricant-based production substitute generates negative values for each impact indicator, which indicates that this technology is an important alternative in the mitigation of impacts and that from the perspective of a circular economy. The process is very complete as it processes used oil to obtain base oil that can be reused [28]. Figure 3(a) shows that the contribution of the natural gas generation flow (flow associated with the need for process heating) generates an impact of 0.237 Kg of CO_2-Eq. In addition, together with transport, from the collection in the main cities and subsequent shipment of these to the plant once the amount of 10,000 gallons is available, are the reference flows with the greatest incidence in the global warming category (contribution of 81.25% for Euro IV vehicle capacity of 3.5 to 7.5 tons and 48.83% for Euro III vehicle capacity of 16 to 32 tons). Influencing the increase in average temperature due to anthropogenic greenhouse gas emissions (melting of glaciers, rising ocean levels, changes in meteorological phenomena), so it highlights that the substitute flow of lubricant-based production under this process allows to reduce -0.472 Kg of CO_2-Eq.

The Figure 3(b-f) shows the impacts associated with baseline fluxes for the categories: freshwater ecotoxicity, freshwater eutrophication, marine ecotoxicity, marine eutrophication, and water depletion. To water and marine ecotoxicity categories Figure 3 (b,d) substitute reference streams for waste oil refining by-products (lubricant-based substitute, fuel oil substitute, naphtha substitute, and diesel substitute) were avoided, and the production of low-sulfur diesel fuel by crude oil refining to be consumed by vehicles transporting used oils both regionally generates the highest environmental impact in these two categories. Substitute reference flows of diesel, base oil, and fuel oil avoid impacts on freshwater eutrophication and only substitute diesel and lubricant-based flows avoid marine eutrophication impacts. The flow of electricity generation (consumed by the refinery and consumed in crude oil distillation processes) generates the greatest impact on freshwater eutrophication, and in the case of marine eutrophication, the most relevant impacts in this category are the production of natural gas and the transportation of oils. For the water depletion indicator (Figure 3f), natural gas production has the highest share of 26.60%, followed by low-sulfur diesel production (used as fuel in vehicles) and electric power generation; On the other hand, the substitute flows of naphtha, fuel oil, diesel oil, and lubricant base allow avoiding the depletion of this if they are obtained as products of the refining of lubricating oils (contributions of 0.9%, 4.37%, 5.91% and 118.28%, respectively). These results indicate that re-refining by thin film distillation proves to be efficient, avoiding consumption compared to the production of fuel derivatives from petroleum.

Figure 3. Categories of the impacts in the re-refining process for each reference flow: (a) Global warming; (b) water eco-toxicity; (c) Water eutrophication; (d) Marine eco-toxicity; (e) Marine eutrophication and, (f) Depletion of water.

Figura 3. Categorías de los impactos en el proceso de refinación para cada flujo de referencia: a) Calentamiento global; b) la ecotoxicidad del agua; c) Eutrofización del agua; d) Ecotoxicidad marina; e) Eutrofización marina y f) Agotamiento de las aguas.

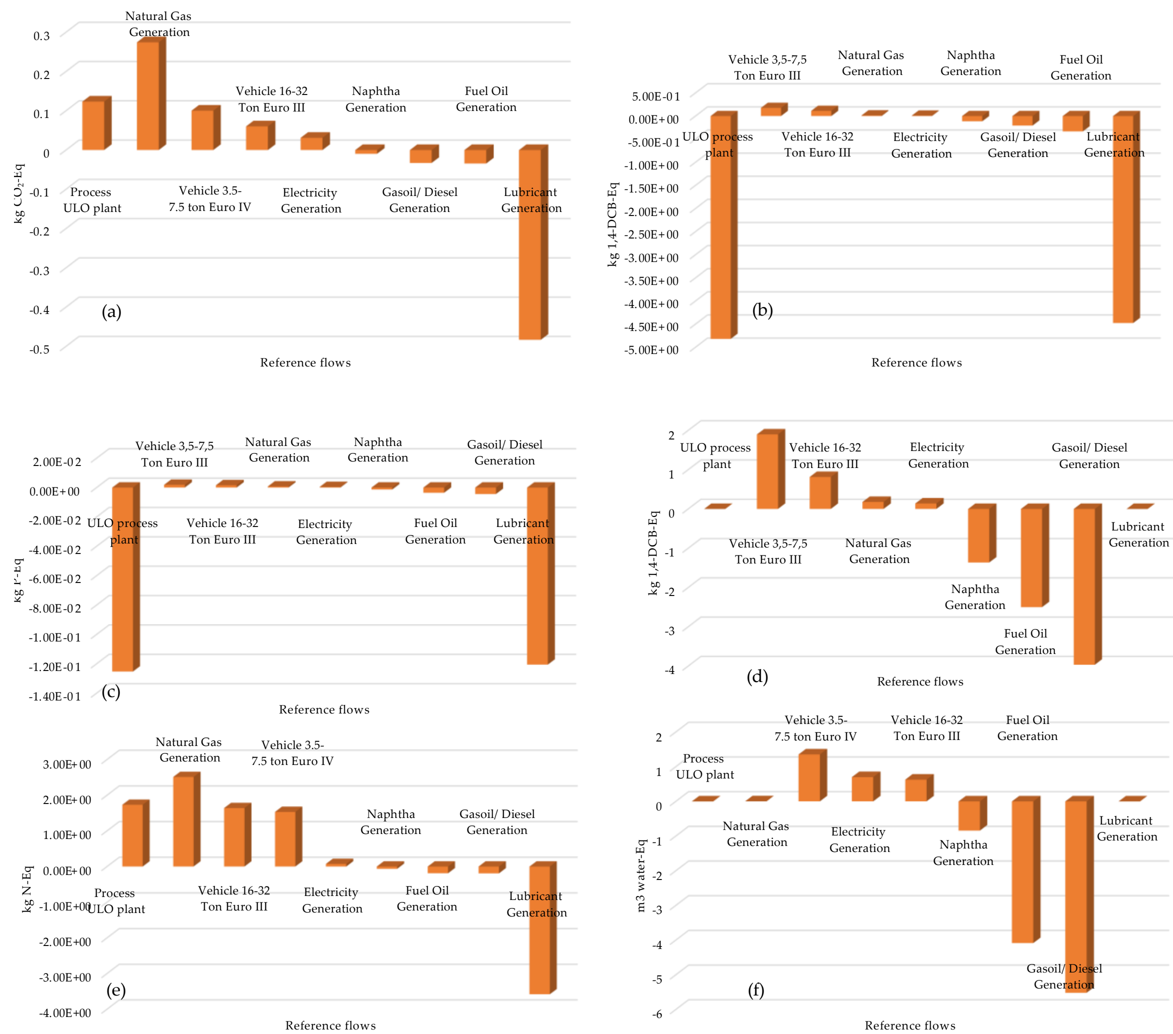
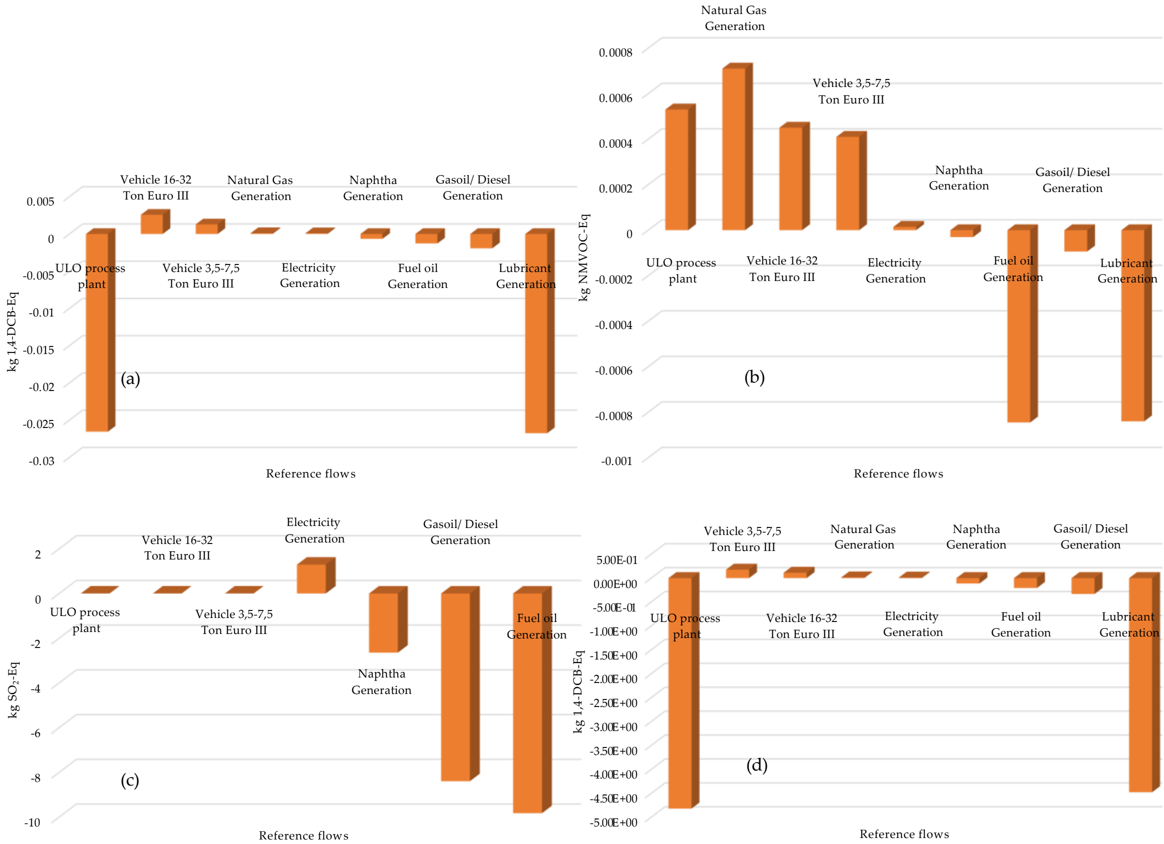


Figure 4(a) shows the impacts associated to the human toxicity indicator, which quantifies any toxicological effects potentially generated by exposure to chemical and biological substances in humans. The reference flows with the greatest impact in this category are the use of tractor-trailer vehicles 16 – 32 ton euro III with a contribution of 9.70% and the production of low-sulfur diesel fuel from the oil it consumes with a contribution of 4.81%, so the combustion process carried out during interdepartmental transport governs such impact. most likely because of the average distance of 697 km and the type of emission standard Euro III. On the other hand, substitute flows of naphtha, fuel oil, diesel oil and lubricant base allow to avoid toxicity in humans if they are obtained as products of the refining of lubricating oils (contributions of 2.5%, 4.8%, 7.4% and 100.8%). Figure 4(b) shows the impacts associated to the photochemical oxidant generation indicator, this Figure shows the reference flows that have the greatest impact on the category of formation of photochemical oxidants is the production of natural gas with a percentage greater than 100% of the total result for this category, followed by transport by vehicle with a capacity of 16-32 ton euro III and transport by vehicle with a capacity of 3.5-7.5 ton euro IV (contribution of 83.51% and 76.3% respectively).

Figure 4. Categories of the impacts in the re-refining process for each reference flow: (a) Human toxicity; (b) Photochemical oxidant generation; (c) Land acidification and, (d) Land eco-toxicity.

Figura 4. Categorías de los impactos en el proceso de refinación para cada flujo de referencia: a) Toxicidad humana; b) Generación de oxidantes fotoquímicos; c) Acidificación de las tierras y d) Ecotoxicidad de las tierras.



The reference flows of fuel oil substitute production and lubricant-based production are the most important flows in reducing the photochemistry impact. The lubricant-based production contributed to reducing the impact category by 156.9% concerning the overall result. Figure 4(a) shows the impacts associated with baseline fluxes for the categories of land acidification and, land eco-toxicity. The most relevant source for the land acidification category is the production of natural gas, followed by vehicle transport with a capacity of 16-32 tons euro III and transport by vehicle with a capacity of 3.5-7.5 tons euro IV (contributions of more than 100% of the result obtained), processes closely related to the use of fossil fuels and which consume a large amount of energy from non-renewable sources, which are compensated with the contribution of the substitute flows of naphtha, fuel oil, diesel, and lubricant base that yield negative values and that, only the flow of base substitute allows to avoid a generation of -0.00144 Kg of SO_2-Eq (a value 10 times higher than the result of this category) [35]. Regarding the terrestrial ecotoxicity category, the flow that has the greatest impact is the production of low-sulfur diesel as a vehicle fuel (no more than 4%), a result very different from that obtained by Silva et. al., where 83.8% of the impacts are associated with the shipment of used oils to the treatment site, although the diesel is the fuel used by the vehicles for transport to the treatment plants for both studies [31]. For this category, only diesel substitute and lubricant-based flows avoid impacts associated with land acidification. This can be related to the reduction in energy and fuel consumption compared to the production of an equivalent mass of new raw material, throughout the life cycle.

Despite the fact that used lubricating oils are considered hazardous waste in Colombia, the basis of the chemical composition of the oil is generally preserved. For this reason, the thin-film re-refining process shows that this technology avoids environmental impacts for the recovery and subsequent reuse of its fuel derivatives from their use for their subsequent commercialization, allowing a guarantee of their circular economy. Mineral oils used by the re-refining process not only offer to avoid a large part of the avoided impacts, but they are a great opportunity for entrepreneurship in the country, creating new jobs and boosting the economy of alternative fuels, allowing to meet in greater proportion the needs of all regions of the country for the management of this waste that today is not enough. Currently, 31% of used lubricating oils are used (re-refining and obtaining energy), 11.5% are finally disposed of to prevent environmental pollution and 57% are managed by bioremediation, physicochemical treatments, and heat treatments (e.g., incineration or the use of autoclaves). About 50% of new lubricating oil turns out to be waste due to unwanted, toxic and environmentally hazardous substances that could have an antagonistic impact on both human health and the environment [34]. The re-refining technology is an alternative viable to carry out an appropriate ULO management to reduce negative impact to environment and human beings.

4. CONCLUSIONS

We applied a LCA to the re-refining technology by thin layer distillation for using the OPENLCA software version 1.11 and the midpoint method of ReCiPe 2016 (H) V1.13. For ten of the twelve simulated impact categories, the lubricant-based production process demonstrated environmental benefits at the substitution stage, which avoids the generation of environmental impacts in the manufacture of this product produced mainly from the petroleum distillation process and indirectly allows the possibility of increasing the future availability of crude oil as a consequence of higher present recycling rates. The technology of re-refining by thin film distillation for the treatment of used lubricating oils, shows significant environmental benefits in the reduction of environmental impacts in the following categories: human toxicity, water depletion, marine ecotoxicity, freshwater ecotoxicity, terrestrial ecotoxicity and freshwater eutrophication, being a viable alternative to be considered as final disposal of the used mineral oils. This can allow the re-refining process in Colombia from a circular economy point of view, to maximize the value and useful life of lubricating oils by keeping them in circulation for as long as possible, instead of being discarded or destroyed once used. Finally, the methodology employed in this work was suitable to carried out the LCA study.

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Declaration of competing interest
On behalf of all authors, the corresponding author states that there is no conflict of interest.

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