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ANALYSIS OF THE REVERSE LOGISTIC CYCLE OF POST-CONSUMPTION LUBRICANT OIL IN TERESINA-PIAUÍ

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ABSTRACT

The continuous growth in population, industry and the automobile sector, combined with the lack of incentives for sustainable consumption, increase the consumption of lubricating oils exponentially. In this sense, the National Solid Waste Policy (PNRS), with Law No. 12,305/2010, instituted the mandatory proper management of lubricating oils and waste resulting from the exchange activity. Resolution No. 362/2005 of the National Environmental Council (CONAMA), in turn, states that oils should be recycled by the re-refining process. In addition, the law determines shared responsibility among all the links involved in the logistics chain for this product. This research sought to analyze the collection of automotive lubricant oil in Teresina, Piauí, Brazil and its compliance with legislation. For this, the city's waste generating points were identified, as well as the monitoring of all stages of the reverse cycle of lubricating oil. The results obtained show that the reverse logistics of used or contaminated lubricating oil (OLUC – *óleo lubrificante usado ou contaminado*) generated in the city does not occur effectively, requiring greater supervision of the establishments that perform the oil change, environmental education for professionals involved in the reverse logistics cycle of waste oil and incentives to open a company that collects and re-refines used oil in the Northeast, which would make the reverse logistics cycle of this product much less expensive. The main practical contribution of this study refers to the observance of the lack of awareness about the dangers of incorrect disposal of OLUC, the difficulty of companies in carrying out the proper packaging disposal in Teresina, the need for specialized companies to carry out the collection of OLUC in the city, and the inspection by environmental agencies that could make them aware. The main limitations of the work were the great difficulty in establishing a list of waste-generating points in the city of Teresina, since the agencies consulted have outdated lists with inaccurate information on the points that collect OLUC; and the conducting of the interviews via telephone call with the collector companies, since re-refining is carried out in the city of Feira de Santana, Bahia. Its originality is ratified by other works, because it is, until its publication, the first and only study developed on reverse logistics of post-consumption lubricant oil in Teresina.

Keywords: Reverse logistics; Lubricant oil; Environmental management; Sustainability; Re-refining.

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1. INTRODUCTION

According to Law 12,305/2010, which established the National Policy for Solid Waste (PNRS – *Política Nacional de Resíduos Sólidos*), solid waste is all:

> "material, substance, object or good discarded resulting from human activities in society, whose final destination is performed, is proposed to perform or there is an obligation to perform, in solid or semi-solid states, as well as gases contained in containers and liquids whose particularities make their release into the public sewage system or into water bodies unfeasible, or require technical solutions or economically unfeasible in view of the best available technology.

In this sense, the Brazilian Association of Technical Standards (ABNT – *Associação Brasileira de Normas Técnicas*), in its technical standard 10.004/2004, classifies used automotive lube oil as a hazardous waste because it presents high toxicity and, thus, represents risks to environmental preservation and to the quality of human health, because its deterioration forms polynuclear aromatic compounds, which are potentially carcinogenic and contaminate soil, air and water, causing processes that threaten aquatic life, such as eutrophication.

In view of such information and aiming at the correct destination of post-consumption automotive lubricant oil, the National Council for the Environment (CONAMA – *Conselho Nacional do Meio Ambiente*) in its Resolution No. 362/2005, Article 3, defines that: "all used or contaminated motor oil collected should be destined for recycling through the re-refining process, since this process enables it to be reused with maximum recovery of the constituents present in the used oil (Brazil, 2005)."

Therefore, to carry out such a process it is necessary to use reverse logistics, which can be defined as the part of logistics that aims to relate topics such as: reduction, source conservation, recycling, replacement, and disposal to traditional purchasing logistics activities. This area of business logistics aims to manage, in an integrated manner, all logistical aspects of the return of goods to the production cycle, adding economic and environmental value to them (Silva; Santos, 2015).

Currently, waste is no longer an undesirable and worthless material, but an economic value, thus becoming raw material for a new product or process. This change is part of the "Waste Reduction Revolution", which comes from the changes that have occurred in society and economy (Deus et al., 2015; Worrel; Vesilind, 2011). Such changes are responsible for the alterations in laws that emphasize the non-generation of waste and the restitution of economic value to it through the implementation of reverse logistics (Brazil, 2010).

The revaluation of a product or material used is one of the main objectives of reverse logistics, mainly because it reduces the aggression to the ecosystem by preventing solid waste from being dumped directly into the environment (Magalhães, 2011). OLUC, due to its degree of contamination, requires adequate logistics infrastructure specifications for its management (Brazil, 2005) and for it to reach the re-refining process, as mentioned above.

Lubricating oils are used to maintain the proper functioning, especially of the engine of cars, buses, trucks, trains, planes, boats, motorcycles and equipment used for various purposes (Comper et al., 2016; APROMAC, 2007). As they are used or are the consequence of accidents, lubricating oils are deteriorated with contamination, losing their initial properties and thus no longer fulfill their initial purpose. Therefore, they need to be replaced to ensure the proper functioning and integrity of the oil-lubricated equipment or engine.

According to Oliveira (2017), the Brazilian lubricant oil market is following the world trend with expectations of growth for the coming years. According to data made available through the website of the National Union of Fuel and Lubricant Distributors (SINDICOM – *Sindicato Nacional das Empresas Distribuidoras de Combustíveis e de Lubrificantes*, 2016), the volume of sales of these goods in 2012 increased approximately 2.9% compared to the previous year. It is estimated that this market reached a value of $4.5 billion in the same year. The demand of the Brazilian lubricant market showed an average growth rate of 2.6% per year between 2002 and 2012, with projected growth in the market of 2.8% for the period from 2012 to 2022 according to data from the National Bank of Economic and Social Development (BNDES – *Banco Nacional de Desenvolvimento Econômico e Social*, 2014)

Despite this growth in industry and in the automotive sector throughout Brazil, the Northeast is a region where the reverse logistics of post-consumption lubricant oil has shown results below the national average. In 2014, 28% of all oil sold in this region was collected, while the national average is approximately 36%. Moreover, according to data from the Interministerial Ordinance No. 100/2016, the expected growth for OLUC collection in Brazil for the coming years is greater for the North and Northeast regions than the rest of the country (Brazil, 2016). This can justify the development of processes that make viable the return of the residue generated in these regions.

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Thus, with the growing population and the country's industrial and automotive sectors, there is a need for studies on post-consumption lubricant oil management channels. The objective is to ensure that all those involved fulfill their role conscientiously and that the final destination of OLUC is environmentally correct and in compliance with current legislation.

2. METHOD

For the development of this research, a bibliographical review on solid residues, lubricating oils and reverse logistics of post-consumption automotive lubricating oil was carried out in the first instance. The bibliographic review was made through books on the subject, as well as articles, dissertations and theses found in scientific databases such as ScienceDirect, Capes Journals and SciELO. Subsequent to this stage, a survey of the legislation in force in Brazil on the subject was conducted through sites such as the Ministry of the Environment and the National Petroleum, Natural Gas and Biofuels Agency (ANP – *Agência Nacional do Petróleo, Gás Natural e Biocombustíveis*).

To determine the population and sample, a Google Maps search was performed on the waste generating points of the city of Teresina. Through this search, the address of 31 gas stations, 12 dealers and 14 automotive centers was found. Later on, the population of gas stations in this work was more accurately determined by means of information collected from public institutions such as the Finance Secretary of the State of Piauí (SEFAZ-PI), which provided a list with 170 gas stations. From these gas stations, by means of telephone calls, it was determined that only 36 performed the oil change activity.

In the application of this survey, the formula proposed by Bolfarine and Bussab (2005), which is exposed in Equation 1, was chosen to calculate the percentage of confidence of the survey after the measurement of the sample through consultation with the posts.

Equation 1

$$n = \frac{N.Z^2.p.(1-p)}{Z^2.p.(1-p) + e^2.(N-1)}$$

In which,

n: Calculated sample

N: Represents the population

Z: Standardized normal variable associated with confidence level

p: True likelihood of the event

e: Sampling error

The population of this survey is the sum of 36 gas stations that collect lubricant oil, 12 dealerships and 14 automotive centers, totaling 62 establishments. For a survey with a 95% confidence level and 7% margin of error, it was obtained a sample with 48 oil change points, which were visited for on-site observation and interviews.

For the interview, a semi-structured script was prepared based on the current legislation and on the surveys of Bulhões et al. (2016) and Simões (2009), which was applied to the managers and/or other employees of the waste generating points in the city of Teresina.

The on-site observation of the oil change application, the infrastructure and the procedures adopted in the change areas was aimed at identifying: (i) how used and/or contaminated lubricant oil generated at the site is stored; (ii) how it is transported; (iii) how and if it is recycled; (iv) how other residues generated in the oil change activity are recycled, such as used lubricant packaging and oil filters; and (v) the agents involved in the post-consumption automotive oil reverse logistics stages in the city of Teresina.

Finally, a questionnaire was developed based on the Canchumani (2013) and Castro (2011) surveys, to be applied in the waste oil collection and re-refining centers that serve the city of Teresina-PI. It was necessary to conduct the interviews via telephone call with these companies, considering that the collectors that serve the respective city are located in the city of Feira de Santana, Bahia.

3. RESULTS AND DISCUSSION

Waste generating points

The research conducted aimed to find several relevant points about the reverse logistics of post-consumption lubricant oil. In this way, the questions were directed in order to find information on how OLUC is collected, on the disposal of its packaging and on the other materials used during the oil change. In addition, information was collected about the companies that collect OLUC and the treatment that this waste oil undergoes after it is collected by these companies.

One of the points raised during the survey was about the inspection of the waste generating points surveyed, which is the responsibility of the environmental agencies (Table 1).

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Table 1. Supervision of waste generating points by environmental agencies

Supervisory Body	Amount
National Petroleum Agency - ANP	37
Brazilian Institute of Environment and Renewable Natural Resources - IBAMA	17
Municipal body	14
No organs	2

Source: The authors (2019)

During the survey it was possible to verify that most of the generating points, according to interviewees, were inspected by more than one environmental agency, such as the ANP and IBAMA. According to Table 1, it can be observed that most of the surveyed points were inspected by the ANP (37). According to BRAZIL (2005) the inspection of the compliance with the foreseen obligations and the application of the appropriate sanctions is the responsibility of IBAMA, state and municipal environmental agencies. Despite this, it should be noted that only 17 and 14 of the points interviewed claimed to have been inspected by IBAMA and the Municipal Agency, respectively. In addition, two of the waste generating points stated that they were not inspected by any agency.

The non-monitoring of the waste generating points can also be observed in other Northeastern states, such as Ceará. Corroborating with this information, according to Costa and Santos (2015), out of a total of 15 establishments surveyed in the city of Fortaleza, Ceará, 14 (93.3%) do not have a license from the ANP or from environmental control agencies. These data expose the fragility of the inspection of the establishments by the competent agencies of such activity in the Northeast region of the country. There is a need for greater control of the adaptation of the waste generating points to the legislation in force on the waste oil exchange and storage activity.

The second point raised was the destination of the residues resulting from the oil change activity. When questioned about what happens to post-consumption lubricant oil packaging and used oil filters, 23.4% of the representatives of the waste generating points stated that this material is delivered to a Teresina company, which carries out the recycling. However, the vast majority of the interviewees (66.7%) dispose of the packaging for ordinary waste. This data shows that there is still a long way to go to effectively raise awareness among those involved in the oil change activity of the harm to human health and the environment that the improper disposal of these contaminated wastes can cause. The percentages on the fate of used OLUC packaging and oil filters can be seen in Figure 2.

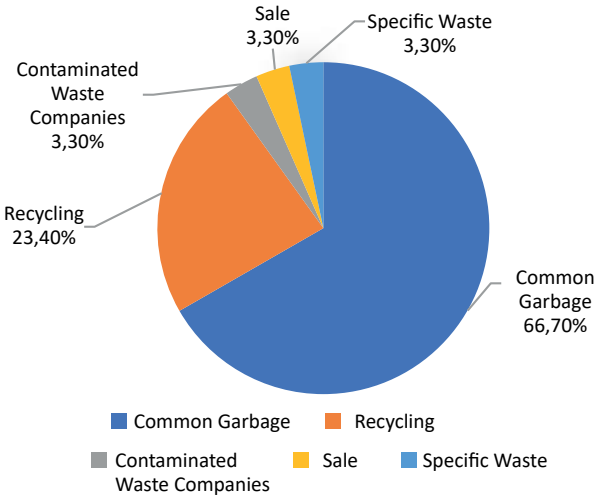

Figure 1. Destination of lubricating oil packaging
Source: The authors (2019)

According to the data presented in the graph in Figure 1, it is evident the lack of awareness about the dangers of incorrect disposal and the difficulty on the part of companies to carry out the environmentally correct disposal of packaging. The lack of specialized companies that carry out this collection in Teresina and the lack of inspection by environmental agencies make such a process flawed. The companies that dispose of packaging for recycling (23.4%) are part of the same group that has partnerships with recycling companies.

Another important aspect about used packaging and oil filters is whether the waste oil run-off process is carried out. In automotive lubricating oil bottles there is a residual oily fraction after the supply of 20g of oil, on average, which remains in the one-liter packages (Lei and Wu apud Martins et al., 2015). In Figure 2 it is possible to observe an oil filter (a) and a used lubricant package (b), respectively, going through the process of residual oil runoff. This process is of great importance for environmental safety, as it prevents contamination. Despite this, 19.4% of the researched waste generating points still do not perform it.

During the survey, it was found that 80.6% of the establishments carry out the process of draining the waste oil that remains in the packages. This shows that they are concerned about contributing to the sustainable development of the environment and that on this specific point there is monitoring necessary for its compliance.

Another important factor related to used lubricant packaging is its storage, which must be packed in impermeable containers that can be covered (APROMAC, 2007), as shown in Figure 3.

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Figure 2. Oil filter and used lubricant packaging through the residual oil draining process.
Source: The authors (2019)

Figure 3. Storage of filters and used oil packaging at a Teresina dealer before being collected for recycling
Source: The authors (2019)

It can be observed, from Figure 3, that used oil filters and packages are stored in a specific container for such function, which is properly labeled, informing that it contains contaminated waste that needs specific management other than the disposal of common waste. This container has a lid and is waterproof, which shows that the establishment surveyed complies with the determinations of current legislation. The packages and filters should only be stored in these containers after the process of draining the residual oil, and later they should be sent for recycling, thus performing the appropriate post-consumption reverse logistics expressed in the legislation.

In relation to the amount of OLUC collected per month by the establishments, it was not possible to accurately measure it, since the interviewees had no form of record about the volumes of lubricant oil sold at their stations. However, in an attempt to overcome this obstacle, estimates were made of this quantity based on data such as the number of cars changing oil per day in the establishment and the amount of oil that is used in this process. Figure 4 shows the data found with the help of the interviews conducted.

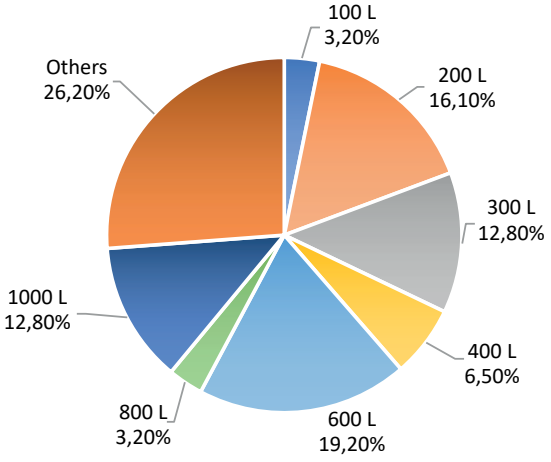

Figure 4. Monthly OLUC collection volume of the establishments
Source: The authors (2019)

According to Figure 4, 19.2% of the establishments collect on average 600 L of OLUC per month, 12.8% collect 1000 L, and 26.2% of the establishments could not estimate the amount of OLUC collected. It can be observed a great variation in the volume of monthly oil collected by the generating points. As explained, this is due to the lack of control that the establishments have over the amount collected, which hinders the analysis with precision on the collection process, since from the volume of lubricant oil, one can estimate the amount of packages that were used by a certain establishment.

Analyzing the data exposed so far, it is possible to estimate an amount of 12,090 liters of oil collected on a monthly basis in all the waste generating points visited (considering all the points visited and the amounts each one receives), which represents an average of approximately 400 liters of OLUC collected per month for each generator. Drawing the process flow and parameterizing it with the percentages found during the research, it is possible to estimate some data about the lubricant oil change in Teresina-PI (Figure 5).

With the help of the Bizagi Modeler simulation software and establishing some parameters for the process, it was possible to estimate the amount of discarded packaging that did not undergo the draining process and where it was discarded. In addition, it was possible to obtain an estimate of where the waste oil from the packages that were drained is destined for.

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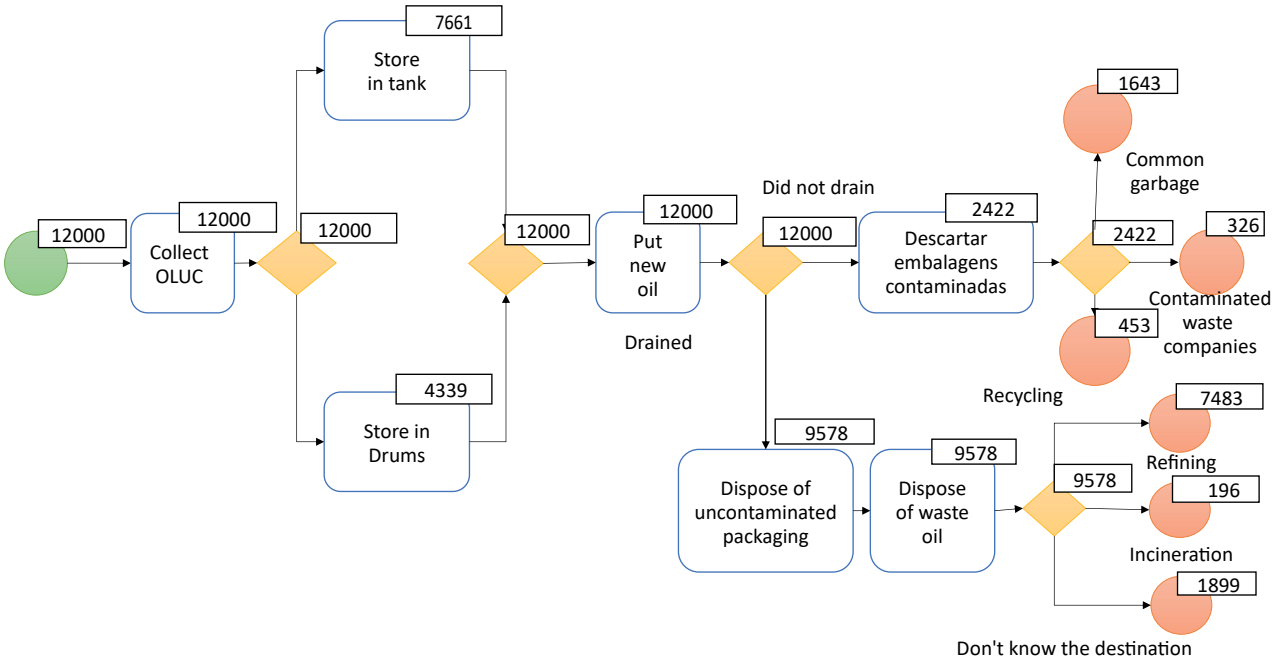

Figure 5. Flow of the lubricating oil collection process
Source: The authors (2019)

Using the 1L lubricant oil package as a basis to parameterize the process and the value in liters collected monthly by the generating points, the following results are obtained: 2,422 packages are discarded without suffering the draining process; of these, 1.643 are disposed of as regular waste, 326 are sent to contaminated waste companies, and 453 to recycling, as can be seen from an analysis of Figure 5. In addition, of the 9,578 packages that undergo the waste runoff process, it can be estimated that the waste oil from 7,843 packages undergoes the re-refining process, and the waste oil from 1,899 packages has an unknown destination.

Another point found during the visits to the establishments and through the collection of information was the lack of a collection and/or re-refining company in the city of Teresina-PI. This fact can be considered one of the critical points in managing the reverse logistics cycle of OLUC in the region, since the lack of a company in the city means that the establishments need to use the services of companies that only have branches in other states of the country.

In addition, the nearest re-refining collector is located in the state of Bahia. This great distance from the collecting company is another critical point, as it causes a delay in the collection of OLUC in the establishments, since to reduce the logistical costs of transporting OLUC, it has been realized that the collecting companies make fewer trips, in which they seek to collect as much OLUC as possible.

In Table 2 it is possible to note a comparison between the city of Teresina and other Brazilian cities located in the states of Ceará, Bahia and Paraíba. It can be observed that the number of interviewees who are not aware of the PNRS in Teresina and Campina Grande, Paraíba, do not present great discrepancies, but in the city of Cruz das Almas, Bahia, this number is much smaller, showing that the agents involved in the city's oil exchange activity are more aware of the PNRS. This better result can be related to the fact that, in the state of Bahia, there are two oil collector/refiner companies, which contributes to a more efficient reverse logistics of this waste and greater dissemination of knowledge among the agents of this cycle.

As for the environmental agencies' inspection of OLUC's exchange, collection and storage activities, the result for the city of Teresina is much better than the result obtained in 2015 in the city of Fortaleza. However, the latter is far ahead of Teresina when comparing the amount of establishments that dispose of lubricant packaging to common garbage, since most of Fortaleza's packaging is disposed of in a more environmentally sustainable way.

Collection and re-refining of the OLUC of Teresina-PI

To better understand the cycle that waste oil goes through, telephone interviews were conducted with employees responsible for the areas of operations, environment and logistics, combined with surveys at the websites of the aforementioned companies that collect post-consumption oil in Teresina, which transport and re-refine it. Such process is fully performed by two companies registered and

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Table 2. Comparison of aspects related to OLUC reverse logistics between Teresina-PI and other Brazilian cities

Topics/Localities	Teresina, Piauí (2018)	Fortaleza, Ceará (2015)	Cruz das Almas, Bahia (2016)	Campina Grande, Paraíba (2016)
Interviewees who do not know the legislation	61.30%	-	25.00%	50.00%
It was supervised by environmental agencies	96.80%	16.70%	-	-
Disposal of packaging in common garbage	66.70%	11.46%	-	-

Source: Costa e Santos (2015); Corrêa e Delgado-Mendez (2016); Nascimento et al. (2016)

authorized by the ANP to perform such activities. The information obtained on the main points questioned during the interviews is summarized in Chart 1.

According to Chart 1, the main information obtained during the survey on Teresina post-consumption oil collectors/refiners is quickly verified. Such information is: the location of the companies, destination that the companies give to the collected waste oil, frequency of collection, means of transportation of OLUC, number of states served by the companies, environmental protection measures that the companies take to ensure the management, safe recycling of post-consumption oil, and the destination of residues from their activities.

According to the interviewees, the frequency of oil collection is carried out daily, but the employees of both companies were unable to accurately inform the average of used oil received by them within a month. To re-refine the waste oil, the companies responded that they transport it in tanker trucks with capacities that vary according to demand to their respective branches, both located in Feira de Santana-BA. The oil stored at the branches is then transported by trailers and tanker trucks to the headquarters of the re-refining companies, located in São Paulo.

Collector companies rely on vehicle tracking devices and volumes transported on their trucks to ensure that waste oil is not diverted for environmentally incorrect purposes. During the interview, it was found that one of the companies currently collects oil in 20 Brazilian states and that the collection center of another company located in Feira de Santana serves the waste oil generating centers in Piauí, Bahia, Sergipe, Maranhão and Ceará. In addition, there are 14 other OLUC collection centers throughout the country that are responsible for collecting waste oil in other Brazilian states.

When asked about the type of establishments from which they receive used and/or contaminated oil, company representatives claim to receive the oil from gas stations, authorized networks, automotive centers, as well as industries,

Chart 1. Summary of the interview with OLUC collector/refiners

Information raised	Company 1	Company 2
Location	Re-refining Matrix: São Paulo – SP Teresina Collecting Branch: Feira de Santana-BA	Re-refining Matrix: São Paulo – SP OLUC Collection Branch of Teresina: Feira de Santana-BA
Destination of OLUC collected	Re-refining	Re-refining
OLUC transport	Tank trucks	Tank trucks
Frequency of waste oil collection	Daily	Daily
Types of customer establishments	Gas stations, authorized networks, automobile centers, as well as industries, farms, transporters, and wind farms	Gas stations, authorized networks, automobile centers, as well as industries, farms, transporters, and wind farms
OLUC average coming from Northeast region of the country received by the company	Does not know how to inform	500,000 liters/month
Collection range of post-consumption oil	Four Northeastern states served by the Bahia branch and other Brazilian regions served by 14 other OLUC collection branches	20 Brazilian states
Environmental protection measures	Water and gas treatment, insurance for environmental accidents and OLUC management training.	Personal protective equipment and signaling equipment, carrying out training on OLUC management.

Source: The authors

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farms, transporters, and wind farms. Furthermore, they affirm to follow CONAMA Resolution No. 362/2005, to issue certificates of receipt to the collector of used and/or contaminated oil, and to send information regarding OLUC and re-refined base oil to the ANP, IBAMA and environmental agencies, when requested.

The stages of the re-refining process used in the companies were not disclosed by the interviewees, but they reiterated that their processes do not generate any type of irreversible waste. In the first company surveyed, contaminated water, due to the re-refining process, undergoes a treatment process and the other waste generated is transformed into asphalt raw material. The information is similar to that found on the second company's website, which shows that, through studies and the application of technologies, the waste resulting from the process is transformed into raw material for the production of asphalt, plastic coatings and for co-processing in cement kilns. During the application of the questionnaires, the interviewees were not able to inform which emission control technologies are used by them.

Both companies claimed to be frequently inspected by ANP and IBAMA, in addition to having environmental management certificates, such as ISO 90001 and ISO 140001. They also constantly carry out training courses regarding OLUC's environmental and management processes.

Both the first and the second companies studied have IBAMA's environmental authorization for the interstate transportation of dangerous products and their representatives informed that they are familiar with the rules governing the re-refining activity. However, they were unable to answer the requirements for the authorization to carry out the OLUC re-refining activity required by the ANP, nor the environmental obligations for OLUC re-refiners, according to CONAMA Resolution No. 362/2005.

Therefore, during the research in the websites of the companies and application of the interviews, the difficulty to obtain information regarding the internal processes of the OLUC re-refinishing companies became evident. There is also a lack of knowledge on the part of many collaborators on issues related to the requirements and responsibilities provided for in current legislation on OLUC management and destination.

4. CONCLUSION

According to the data presented, it can be observed that the waste generating points still use few control mechanisms to avoid the disposal of contaminated packaging in the environment. In spite of complying with the determinations of the legislation that regulates the treatment of lubricating oil, the generating points find obstacles for the correct disposal of their packages that, in most cases, are discarded in the common garbage due to the lack of specialized companies in the collection of contaminated garbage in Teresina.

Another point that showed that the OLUC reverse logistics does not occur effectively in the city was the finding that some generating points do not know the destination of the waste oil removed from post-consumption packages. This fact also indicates a lack of inspection by environmental agencies in places with lower demands for OLUC collection.

Thus, it was observed during the survey that generator stations with higher volumes of lubricant oil collection perform safer processes, with lower residue generation. The points with lower collection volume have poorly defined processes that end up causing damage to the environment because of the incorrect destination of both the packages used and OLUC.

Finally, it is very difficult to establish a list of waste generating points in the city of Teresina, considering that some environmental agencies were consulted, but have outdated lists with inaccurate information about the points that perform OLUC collection. It is observed the need for waste oil collectors and re-refiners in the Northeast, given the great distance between the collection points. In addition, the re-refiners increase the time needed to perform the complete reverse logistics cycle of OLUC and make such a costly logistics of financial resources.

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