

Environmental Sustainability and Reverse Logistics: An Analysis of the Recycling Networks of Cooking Oil Waste in Sao Paulo, Brazil

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Abstract—The recycling of used cooking oil is gaining increasing attention as society begins to realize the environmental, economic and social benefits of this activity. The reuse of cooking oil has not only prevented its inappropriate disposal but has also yielded economic and social benefits via the valuation of cooking oil waste as a raw material and the possibility of generating employment and income. This study aims to analyze how cooking oil recycling networks are formed to identify ongoing initiatives of collection and reuse, as well as to understand the processes of both formation and expansion of these networks. At present, a number of Civil Society Organizations of Public Interest (CSOPIs) and nongovernmental organizations (NGOs) are spreading this idea and forming networks among suppliers of used oil (final consumers), collection points, processors (companies that collect, filter and sell the product) and companies that use the recycled oil as a raw material. This study examined two of these organizations (Ecóleo, an NGO, and Triangle Institute, TI, a CSOPI) to obtain a preliminary overview of a number of existing initiatives for the collection and recycling of cooking oil in Brazil and the networks that are being formed around these initiatives, including their dynamics and expansion perspectives.

I. INTRODUCTION

Shared responsibility for the waste generated throughout lifecycle of products and the need to implement reverse logistics systems at the industrial sectorial levels are issues that have been on the political agenda for decades. However, only after Law 12.305 (National Policy on Solid Waste, NPSW) was passed on August 2, 2010, did a number of social actors truly become involved in these discussions. This law was regulated by Decree 7.404 enacted on December 23, 2010, which established shared responsibility between both individuals and companies for the generation and management of solid waste [1].

Cooking oil waste is among many materials that can be recycled, such as plastic, paper, cardboard, glass, aluminum, styrofoam, tires and wood. When disposed of correctly, this oil waste can be used in resins for paints and varnishes, detergents, soaps, fabric softeners, soaps, pet feed, glycerin, lubricants for engines and biodiesel [2].

On the other hand, when this oil waste is disposed of improperly (e.g., poured down the drain) with other types of waste, it usually (i) forms a crust of dirt, clogging the internal facilities and sewage systems, and (ii) pollutes rivers and groundwater, threatening aquatic ecosystems and the public water supply. According to [3], one liter of oil can

contaminate approximately 25 liters of clean water. Ecóleo, a NGO dealing with the recycling of cooking oil in Sao Paulo, mentions that approximately 2.4 billion liters of this waste are improperly disposed of each year in Brazil. This number is quite impressive considering that the estimated annual production nationwide is approximately 3 billion [4].

Given that most of the Brazilian population still does not recycle cooking oil waste and that several NGOs and CSOPIs are involved with this type of work, the research question designed to guide this study was: *How are networks of cooking oil waste recycling formed in the Metropolitan Region of Sao Paulo and what are the major challenges faced by these networks?*



Figure 1: Location of the Metropolitan Region of Sao Paulo (not to scale) in Sao Paulo State, Southern Brazil

To answer this question, we first had to identify some NGOs and CSOPIs that have been collecting and preparing this type of waste for recycling in the Metropolitan Region of Sao Paulo over the last few years. Next, we needed to try to understand the processes of the formation and expansion of the collection networks. In addition, we also analyzed the existing links between population, collection points and recyclers as well as the similarities and differences among agents involved in the whole recycling process, from the collection of the waste to its final use.

The remainder of this article is organized into four primary parts: a literature review, a description of the research methodology, the results and a discussion thereof and final remarks.

II. LITERATURE REVIEW

The literature review is divided into four main areas: networking, major regulations pertaining to waste recycling, reverse logistics and the recycling of cooking oil waste in Brazil and abroad.

A. Network formation

According to [5], network theory can be understood as an analysis of how different actors involved in a network (people, organizations, environment) interact with each other based on their interests in exchanging goods and materials (tangible) or ideas and values (intangible).

According to [6], the differences in how individuals are connected can influence their behavior. They emphasize that the more connections exist, the more these individuals are exposed to a larger and more diverse amount of information.

From a sociological perspective, [7] refers to the network as a set of interconnected nodes, noting that, historically, its use has been common worldwide, but this concept recently became much more widely known with the advent of the internet. To [8], the internet has created a virtual space, interconnecting the world, providing unlimited information through these networks and contributing to the formation of social networks. Thus, access to information has become much faster and communication between people and companies much easier [7].

Social networks that have emerged in the virtual environment (e.g., Facebook, Orkut, LinkedIn) have played a key role in interconnecting individuals, allowing them to quickly form alliances and efficiently solve social issues, democratize information and provide social inclusion [8].

One type of network that is worth mentioning is the network of cooperatives for waste recycling in Brazil. The Program for the Reuse of Vegetable Oil (PROVE), created in 2007 by the Government of Rio de Janeiro State, is an example. This program organized these cooperatives into a network to join forces in the collection and sale of used cooking oil, eliminating the middlemen between collectors and buyers. The purchase of recycled oil is guaranteed by the government to produce biodiesel in the Manguinhos Refinery [10]. This case of network formation has proved exemplary, arising as a viable option for strengthening the cooperative alternative, as it allows the negotiation of better prices on product sales.

B. Major regulations pertaining to waste recycling

Cooking oil waste is one of the major causes of water degradation, with a direct impact on this natural resource due to improper disposal. Water is a limited public domain resource that must be protected and consciously used without waste.

To ensure water protection, the Brazilian government issued Federal Law N° 9.433 on Jan 8th, 1997, creating the National Policy on Hydric Resources and the National System of Hydric Resources Management (or SINGREH in

Portuguese) with specific objectives, including to “ensure that current and future generations have water available in quality standards suitable to each use” [11].

On the other hand, the National Policy on Solid Waste (or PNRS in Portuguese) stresses in chapter 2, article 3, paragraph VII, that an environmentally adequate final destination for waste is one that

Includes the reuse, recycling, composting, recovery and energetic usage or other allowed destinations according to competent members of Environmental National System (SISNAMA in Portuguese), National System of Sanitary Vigilance (SNVS) and Unique System of Agriculture and Livestock Health (SUASA), amongst them the final decision, observing specific operational rules to avoid risks or damages to public health, to safety and to reduce adverse environmental impacts [1].

In paragraph XVII of this document, which concerns shared responsibility, there is no clear indication of how to identify producers, importers, distributors and/or resellers of vegetable oil, as stated in this paragraph. In addition, a clear specification regarding cooking oil waste treatment or the destination thereof is absent in this regulation (PNRS), hindering action proposals to minimize the environmental impact.

Prior to PNRS, São Paulo State issued Law n° 12,047 on Sep 21, 2005, creating the State Program of Oils and Fats from Vegetal and/or Animal Sources and Cooking Oil, aiming to prevent damage to sewer systems and the pollution of potable water sources, inform the population about the environmental risks of improper disposal and the benefits of recycling, encourage the practice of collecting and recycling oils and fats and promote the economic exploitation of recycling oils and fats to generate jobs and income for small businesses [12].

Resolution 430/2011, issued to improve Resolution 357 from March 17, 2005, by the National Council of the Environment (CONAMA), which regulates the conditions and standards of waste disposal, states that “vegetable oils and animal fats cannot be discharged into water in concentrations higher than 50 mg/L” [13].

In the Municipality of São Paulo, Law 14.487 of July 19, 2007, instituted the Awareness Program for the Recycling of Oils and Fats from Culinary Usage [14], which was issued as a Regulation on December 1, 2008, under number 50.284 [15].

The main objectives of this Law are to create awareness and inform the public as well the owners and employees of meal and food production companies that use oils and fats about disposal issues. Furthermore, this Law seeks to stimulate, promote and foster educational campaigns concerning the proper destination of oil waste.

The same regulation (50.284) also created Law 14.698 of February 12, 2008, with a specific clause on the “prohibition

of used cooking oil waste disposal into the environment” [16].

As described above, Brazil has several laws and regulation on multiple levels (Federal, State and Municipal) to ensure that every stakeholder is aware of the correct methods of disposing of cooking oil waste. Because the potential for the collection of cooking oil in Brazil is enormous and the amount of cooking oil disposed of improperly is 200 million of liters/month, additional incentives and improvements on existing programs are essential for identifying the best alternatives and encouraging all stakeholders to become involved and continuously participate in waste separation and disposal.

C. Reverse logistics

Reverse logistics is the area of logistics that involves planning, operating and controlling the return flow of goods and materials from post-sales and post-consumption back to the productive chain. In other words, this is the activity responsible for the return of raw materials, packaging or goods to be recycled or reused [17].

According to the Council of Supply Chain Management Professionals (2010) [18], recycling is the reverse channel of revaluation, in which the constituent materials of discarded products are industrially extracted and transformed again into raw (or secondary) materials to be reincorporated into the production of new products.

In PNRS, chapter II, article 3, paragraph XII, reverse logistics is defined as

an instrument to economic and social development, characterized as a set of actions, procedures and means devoted to make feasible the collection and restitution of solid waste to industrial sector to reuse on life cycle on its own productive cycles or other proper environmental final destination [1].

Furthermore, in this document, reverse logistics is instituted as a tool to articulate the return flow of several post-consumption wastes to producers [19]; however, cooking oil is not included in this scope. However, the creation of feasible measures to return such waste is crucial due to the damage to the environment resulting from improper disposal.

D. Cooking oil recycling

Cooking oil waste can be used to several ends, such as in animal feed, soaps, biodiesel, paints and varnishes [4]. The usage and resulting benefits to the environment are briefly described below.

The generation of energy from fossil fuels (diesel and gasoline originating from petroleum) creates environmental problems and strongly contributes to air pollution via the generation of particulate matter (PM), nitrogen oxide (NO_x), hydrocarbons (HC), sulfur oxide (SO_x) and carbon monoxide (CO), among many compounds, harming both the environment and human health [20]. Due to the problems that fossil fuels can cause by affecting air quality and the people’s quality of life, it is necessary to find alternatives enabling renewable and clean energy generation.

Among several initiatives concerning existing renewable energy is the use of biodiesel, which can be produced from vegetable oils, animal fat and residual oils and fats [19].

One of the questions raised about biodiesel production is the use of farmland to produce food products used exclusively for fuel production. However, in the case of residual cooking oil, its original life cycle is already complete. Thus, biodiesel produced using this oil would be more sustainable than that produced using virgin oil.

The production of biodiesel from residual cooking oil is one way to enhance air quality, prevent this product from being disposed of improperly and thereby polluting soils and rivers and generate job and income opportunities.

Biodiesel production could be further improved if the residual cooking oil producer also uses this biodiesel, closing the loop of the company’s scope.

According to the Project of Law 295/2007, which resulted in Law 14.487/2007, biodiesel is “biofuel produced from a renewable source as the matrix in its productive chain and used in engines based on internal combustion and ignition by compression” [14].

To produce biodiesel from residual cooking oil in a feasible way, specific environmental awareness efforts concerning who will be involved in the process are necessary.

Biodiesel production is highly sustainable, as it contributes favorably to environmental, economic and social areas, as shown in Box 1.

Environmental	<ul style="list-style-type: none"> • Its adequate disposal prevents soil and water contamination by waste and effluents. • It is less polluting than fossil fuels, preventing air quality deterioration and negative effects on public health. • It does not occupy planting area, as it is already a product to be discarded.
Economic	<ul style="list-style-type: none"> • It avoids costs related to the cleaning and maintenance of rivers and sewers. • The raw materials are free (or low in cost).
Social	<ul style="list-style-type: none"> • Its collection, processing and production contribute to the creation of jobs and income for the poorest.

Box 1: Contributions of biodiesel production using cooking oil waste to environmental, economic and social areas

Steps	Brief Description
1. Filtration, Sedimentation and Storage	When the cooking oil waste arrives at the plant, it is filtered with a sieve. The oil is then left in the tank for decantation to separate any dirt that may be present. Next, the oil is stored in reservoirs.
2. Mixing/Heating	From the reservoirs, the oil is placed in a pan and heated to 60°C. After being heated, the oil is processed to form the base pulp of the soap.
3. Drying	The pulp prepared previously is dried.
4. Cut/Crimp Frequency	After drying, the pulp is cut into regular pieces (soap bars).
5. Packing/Stock	To complete this process, the soap bars are packed and properly stocked.

Box 2: Soap production procedure when using cooking oil waste

Source: adapted from [21]

In addition to the aspects listed in Box 1, another common use of cooking oil waste is soap manufacturing. In this case, the law requires that a licensed chemist follow a given manufacturing process to guarantee the proper dosage of chemicals. However, this procedure is generally not followed because soap is frequently homemade. The soap production steps using cooking oil waste are as presented in Box 2.

Despite the complexity of the case presented in Box 2, some people make soap at home without using personal protective equipment (PPE; e.g., gloves, special glasses, apron), which is harmful to both human health and the environment.

III. RESEARCH METHODOLOGY

To achieve the objective of this study, we performed a qualitative study of the collection and reuse of cooking oil waste and the process of networking among the actors involved. The research was based on a literature review, documental analysis and interviews. As suggested by [22], a set of pre-defined keywords were defined to pursue relevant information in electronic databases, laws and regulations as well as theses and dissertations. The interviews were carried out as part of a participatory study performed by the primary author of this paper because she works for the Triangle Institute (TI) as an environmental agent.

By utilizing various research methods, this study falls within the context of mixed methods, which, according to [23] "focuses on collecting, analyzing, and mixing both quantitative and qualitative data in a single study or a series of studies". Mixed methods are suited to investigating problems in which a single source of data is insufficient and the results require a second method to support the primary method used [24].

Throughout the study, survey questionnaires were applied and interviews were conducted with (i) people who delivered cooking oil waste to exchange for soap and other cleanup products in the Parque das Nações Coop Supermarket in Santo Andre city and (ii) the wholesaler Makro of Sao Bernardo do Campo city. The data gathered in this survey were analyzed using Excel flowcharts.

IV. RESULTS AND DISCUSSION

Some CSOPI and NGOs identified during the exploratory phase of this research are carrying out the collection and recycling of cooking oil waste, forming a recycling network with its partners and associates, thereby increasing the number of people involved and the amount of oil collected. This section describes the following elements of the activities performed by a CSOPI called Triangle Institute (TI) and an NGO called Ecóleo: (i) how they became involved in the collection and reuse of cooking oil waste, (ii) how their activities have developed throughout the years and (iii) how their networks with other social actors have evolved.

A. Triangle Institute (TI)

This CSOPI began its activities in 2002 in Santo Andre, Sao Paulo State, as an NGO named Action Triangle. Its initial goal was to improve public awareness regarding sustainable attitudes toward the negative environmental impacts of the incorrect disposal of cooking oil. Because this action was well received among city residents, the Action Triangle gained public recognition in the region and became a CSOPI in 2004, becoming the Triangle Institute (TI).

In January 2012, the TI launched a campaign named "Join Oil" based on building sustainable networks, with schools, small retailers, condominiums, churches, neighborhood associations, clubs and companies as potential partners. The idea behind the campaign is that people can exchange the cooking oil waste for locally produced soap at these locations.

The exchange of cooking oil waste for soap is a way to connect people to the recycling network, encouraging them to separate this waste to be reused and thereby preventing the contamination of the urban drainage system.

In addition to collecting and transporting the cooking oil waste for reuse, the TI has also focused its efforts on environmental communication as a strategy to broaden its collection points and recycling network. Environmental agents hired by this CSOPI engage in dialog with people responsible for potential collection points, trying to convince them about the importance of becoming new links in the cooking oil waste network. The TI's network regarding the collection of oil waste is shown in Fig. 1.

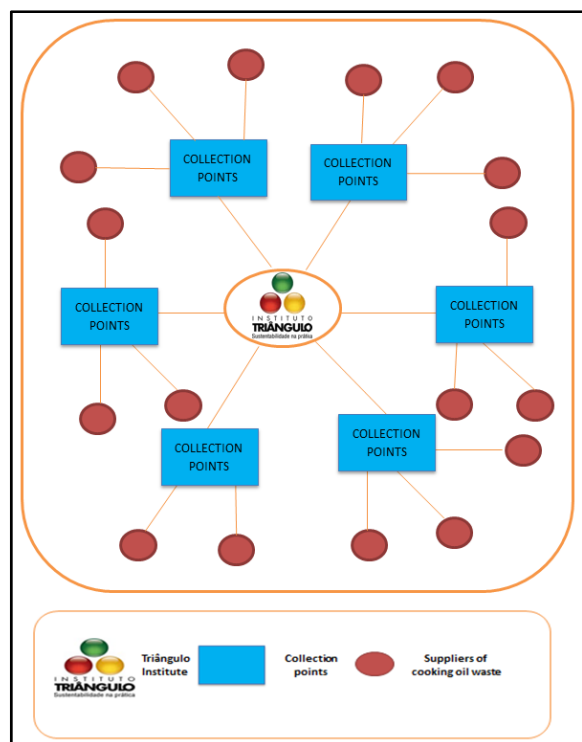


Figure 1: Network showing the flow of the cooking oil waste collected by the Triangle Institute

Fig. 1 shows that the TI is the focal point of a network, surrounded by collection points at which the oil waste suppliers (which gravitate around the collection points) dispose of the oil waste. These collection points facilitate not only the oil waste collection but also the delivery by suppliers. It is also a place for the Institute to disseminate

information about its initiative in an attempt to increase the number of collection points. In this regard, environmental agents frequently convey information to the population about the environmental benefits of oil waste recycling, the “Join Oil” campaign and the geographic locations of the collection points nearby and at the regional level. They also distribute leaflets in free markets and huge supermarkets (e.g., Coop) and wholesalers (e.g., Makro).

In an email survey of 260 TI collection points, 104 representatives responded to a question about the motivation of the organization (company, school, other) for delivering its cooking oil waste to the Institute. The responses to this survey are summarized in Table 1.

The analysis in Table 1 shows that among the reasons for agreeing to deliver cooking oil waste to the Triangle Institute, the most popular responses were (i) to protect the environment (98.0% of respondents), (ii) to present a good image at the collection point (being perceived as an environmentally friendly organization; 64.4% of respondents) and (iii) to collaborate with the Institute (56.7% of respondents).

The survey participants (104 respondents) also answered a question regarding potential motives that would lead them to shift from the Triangle Institute to another partner that collects oil waste. The results are presented in Table 2.

Table 2 shows that the factors that would be most likely to eventually motivate the representatives of the collection points to shift from TI to another collector (partner) are if the other collector had more appealing social projects (46.2%) and if it offered cleaning products other than soap in exchange for the oil waste (18.6%).

TABLE 1: FREQUENCY OF RESPONSES REGARDING MOTIVATIONS FOR DELIVERING COOKING OIL WASTE TO THE TRIANGLE INSTITUTE (104 RESPONDENTS)

Motivations	Agreement	Neutrality	Disagreement
To protect the environment	98.0%	0.0%	2.0%
To collaborate with the Triangle Institute	56.7%	26.0%	17.3%
To attract the public/customers to the collection point	16.4%	9.6%	74.0%
To present a good image at the collection point	64.4%	18.3%	17.3%
To obtain soap bars	13.5%	16.3%	70.2%

TABLE 2: FREQUENCY OF RESPONSES CONCERNING POTENTIAL REASONS THAT REPRESENTATIVES OF COLLECTION POINTS WOULD SHIFT FROM THE TRIANGLE INSTITUTE TO ANOTHER COOKING OIL WASTE COLLECTOR (104 RESPONDENTS)

Motivations	Agreement	Neutrality	Disagreement
If the Institute stopped providing soap bars for exchange	16.3%	18.3%	65.4%
If another collector (competitor) paid in cash	9.6%	10.6%	79.8%
If another collector had appealing social projects	46.2%	28.8%	25.0%
If another collector provides cleanup products other than soap	18.3%	19.2%	62.5%

During the campaigns to collect cooking oil waste in the Coop Supermarket (Santo Andre city) and at Makro Wholesaler (Sao Bernardo do Campo city), 198 people were interviewed. The purpose of these interviews was to identify the leading factors that motivate people to recycle cooking oil waste and submit it to the TI network.

We chose to question the public about the factors that motivated individuals to deliver waste cooking oil to TI collection points. The results of this survey are summarized in Fig. 2.

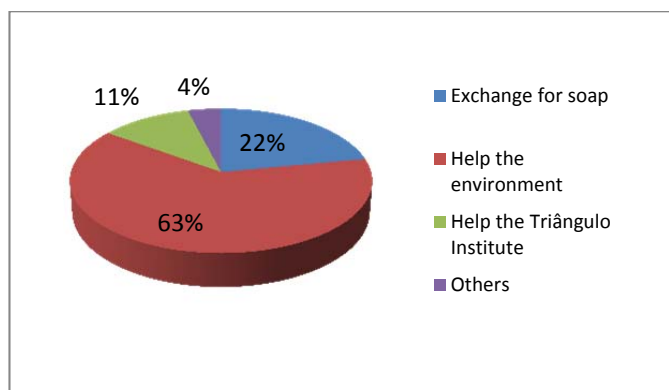


Figure 2: Factors motivating the delivery of waste cooking oil to the Triangle Institute collection points (198 respondents)

Fig. 2 shows that most respondents (63%) sent their cooking oil waste to TI collection points to protect the environment, while 22% responded that exchanging it for soap is a good deal. These results agree with the results obtained in a previous survey carried out at the TI exchange points, indicating that there is currently some level of

environmental consciousness regarding oil waste recycling, even among the poorest.

B. Ecóleo

Originally named Sociedade dos Amigos e Moradores (Society of Friends and Residents of Cerqueira César Neighborhood, SAMORCC), this NGO's activities began in March 2001 in the Municipality of Sao Paulo, aiming to improve the quality of life of local people by adopting sustainable attitudes. In the very beginning, it started a campaign for the selective collection of solid waste that was very successful.

In 2007, SAMORCC launched a campaign for a door-to-door collection of cooking oil waste in specific communities (e.g., *Jardins* and *Consolação*) of downtown Sao Paulo. Folders and posters were used in this campaign, leading to the identification of 1,000 condominiums interested in collecting cooking oil waste in small plastic containers.

To broaden the scope of the cooking oil collection campaign, Ecóleo has partnered with SABESP (a state company concerned with sanitation and the water supply in Sao Paulo). In this partnership, employees of this company were in charge of distributing folders and posters on how to properly discard oil waste when delivering water bills to residents.

Because SAMORCC was very successful in its waste recycling campaigns, in 2009, it was transformed into a non-profit organization named Ecóleo with the aim of organizing the collection of cooking oil waste by region. This NGO functioned as an association of the suppliers of this waste, collectors (collection points) and renderers/recycling companies as associate members, as shown in Fig. 3.

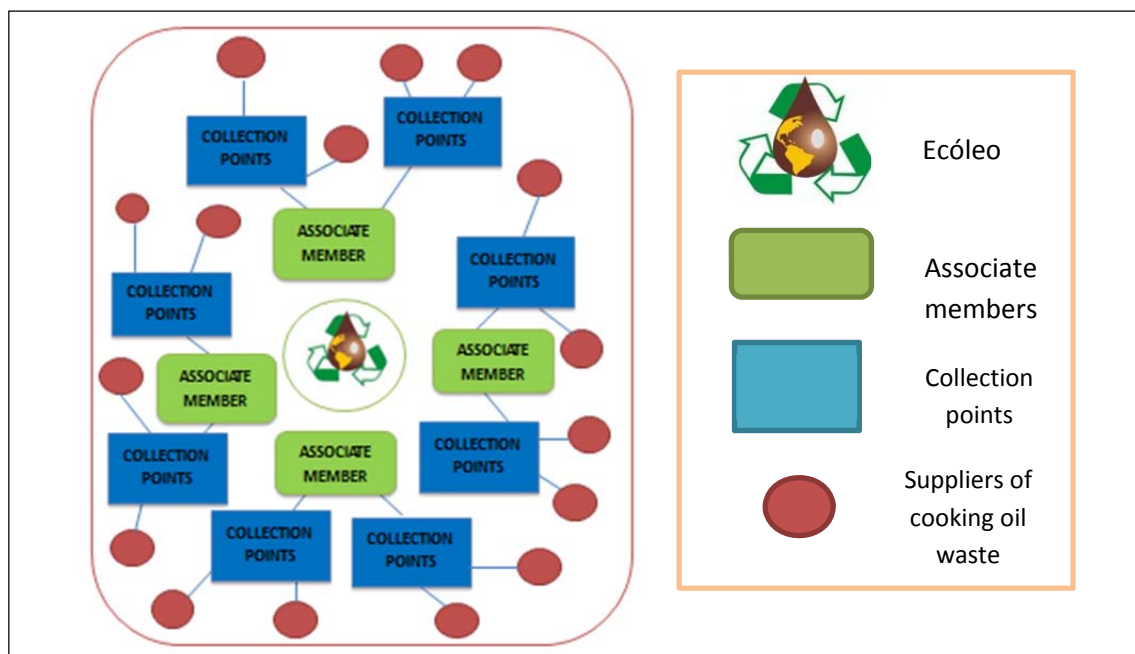


Figure 3: Network showing the flow of the collection of cooking oil waste coordinated by Ecóleo

Fig. 3 shows how the recycling net centralized by Ecóleo is organized, featuring several sub-nets headed by associated members (companies) that are linked with the corresponding collection points or voluntary delivery points (suppliers). The collection points shown in this figure also include individual collectors and others organized into cooperatives.

The suppliers of cooking oil waste include the general public, commercial establishments, industries and small businesses. It is important to emphasize that Ecóleo does not work operationally or commercially but supports and organizes, together with other partners, programs and campaigns for the correct disposal of oil waste. Presently, Ecóleo's network includes 25 associated members from 60 different municipalities, all of which are legally constituted and completely adhering to the environmental requirements stated by law. It has been estimated that Ecóleo's actions have resulted in the creation of approximately 1200 direct and 800 indirect jobs. The present challenge of this NGO is to spread its network throughout the country to encompass over 5,500 cities [4].

V. FINAL REMARKS

The waste cooking oil recycling networks in Sao Paulo are not fully consolidated, as they are still being formed. This is more evident in the case of the Triangle Institute because this CSOPI must very frequently address both retaining the loyalty of representatives of its collection points in terms of the continuity of the supply of the cooking oil waste and increasing the number of its collection points. To reach these goals, the Institute hired environmental agents to carry out sensitization and awareness campaigns.

Ecóleo is the most well-structured organization of this type, acting as the "focal point" of the largest recycling network of cooking oil waste in Brazil. This NGO is partnering with institutions in Canada that are interested in adapting its operational model to oil waste recycling in that country.

Ecóleo argues that those who wish to donate their oil do so to needy people or cooperatives of collectors. For those who wish to sell it, the NGO suggests selling it to processors or collectors. This way, income generation can take place for the poorest and the end of the supply chain. Ecóleo also stimulates the creation of collection points ("ecopoints") with large oil storage capacity as a way to create new opportunities for entrepreneurs to develop their own oil processing companies. In addition, Ecóleo always encourages its partners to carry out sensitization and awareness activities regarding oil waste recycling with the population.

TI is the "focal point" of an oil waste recycling network operating in the ABC Paulista region (the surroundings of Sao Paulo city), encompassing a number of collection points and suppliers. Through its environmental agents, it conducts campaigns on the importance of recycling cooking oil waste at various locations (condominiums, restaurants, bars,

businesses, schools). The oil collected by this organization is used in biodiesel and soap manufacturing.

One problem faced by TI is the frequent disconnection of collection points, as some of them tend to deliver their oil to collectors that offer better prices. These disconnections have been more frequent in recent years due to increased demand for oil waste to manufacture biodiesel. In this scenario, oil waste suppliers have been able to obtain cash payments, rather than simply donating it or exchanging it for soap at collection points.

The results of surveys carried out in TI's campaigns in a supermarket (Coop) and wholesaler (Makro) provide evidence that the public is becoming aware of the environmental problems arising from the disposal of waste oil into the sewer system. In this regard, environmental agents working for TI believe that a well-designed strategy for raising awareness about oil waste recycling can benefit both the Institute (by expanding the collection points) and society (by increasing the volume of oil collected).

The formation of networks of collectors and recyclers of waste cooking oil provides indications that the operational models developed by both the Triangle Institute and Ecóleo create important connections among all of the social actors involved in this process. In practice, however, these two organizations must be constantly vigilant about retaining suppliers, collection points and associate members (companies) in the networks in which the organizations serve as focal points by conducting environmental campaigns.

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