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Factors influencing the return of post-consumer fluorescent lamps through reverse logistics in São Bento do Sul/SC (Brazil)

Fatores de influência no retorno de lâmpadas fluorescentes pós-consumo por meio de logística reversa em São Bento do Sul/SC (Brasil)

Factores que influyen en el retorno de lámparas fluorescentes posconsumo mediante logística inversa en São Bento do Sul/SC (Brasil)

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ABSTRACT
This article addresses the sectoral agreement on sodium and mercury vapor fluorescent lamps and mixed light, within the management of Reverse Logistics Systems, an instrument of the National Solid Waste Policy. The general objective of this study was to identify the main factors that influence the quantities of returns of unusable products from the aforementioned system through Reverse Logistics in the city of São Bento do Sul/SC. For this purpose, data collection was carried out with domestic consumers, store owners and the manager of the city's waste collection system. Afterwards, the opinions expressed by the respondents were analyzed, pointing out possible factors and trends regarding the research object. Thus, this research contributed, in addition to the identification of influencing variables, to possible trends in consumer consumption and disposal behavior, thus enabling the acquisition of a conceptual basis and suggestions for the continuation of this research within the theme of reverse logistics.

Keywords: fluorescent lamps, reverse logistics, national solid waste policy, sectoral agreement.

RESUMO
Este artigo aborda o acordo setorial de Lâmpadas Fluorescentes de vapor de sódio e mercúrio e de luz mista, dentro da gestão dos Sistemas de Logística Reversa, instrumento da Política Nacional de Resíduos Sólidos. O objetivo geral deste estudo foi identificar os principais fatores que exercem influência nos quantitativos de retorno de produtos inservíveis do referido sistema por meio da Logística Reversa na cidade de São Bento do Sul/SC. Para isto, foi elaborada coleta de dados junto a consumidores domésticos, lojistas e gestor do sistema de coleta de resíduos da cidade. Após, foi executada a análise das opiniões emitidas pelos respondentes, apontando possíveis fatores e tendências acerca do objeto pesquisado. Assim, esta pesquisa trouxe como contribuição, além da identificação de variáveis de influência, as possíveis tendências de consumo e comportamento de descarte dos consumidores, possibilitando então auferir uma base conceitual e sugestões para a continuidade desta pesquisa dentro do tema da logística reversa.

Palavras-chave: lâmpadas fluorescentes, logística reversa, política nacional de resíduos sólidos, acordo setorial.

RESUMEN
Este artículo aborda el acuerdo sectorial sobre lámparas fluorescentes de vapor de sodio y mercurio y luz mixta, dentro de la gestión de los Sistemas de Logística Inversa, instrumento de la Política Nacional de Residuos Sólidos. El objetivo general de este estudio fue identificar los principales factores que influyen en las cantidades de devoluciones de productos inservibles del citado sistema a través de Logística Reversa en el municipio de São Bento do Sul/SC. Para ello se recogieron datos de consumidores domésticos, comerciantes y del gestor del sistema de recogida de residuos de la ciudad. Posteriormente se realizó el análisis de las opiniones expresadas por los encuestados, señalando posibles factores y tendencias respecto al objeto investigado. De esta forma, esta investigación contribuyó, además de a la identificación de variables influyentes, a las posibles tendencias de consumo y comportamiento de descarte del consumidor, permitiendo así la creación de una base conceptual y sugerencias para la continuación de esta investigación dentro de la temática de la logística inversa.

Palabras clave: lámparas fluorescentes, logística inversa, política nacional de residuos sólidos, convenio sectorial.

1 INTRODUCTION

Abstract: Humanity has observed harmful consequences to the environment, mainly due to the increase in the generation of solid waste that occur by several factors such as technological advancement, the growth of the world population as well as its increasingly consumerist trends, and the incorrect disposal of this waste, generating enormous environmental liabilities. According to Dias (2011), in this sense, corporations seek new alternatives not to be seen by society

as villains.

In this sense, we highlight the studies of several researchers on different Reverse Logistics Systems and the myriad of factors and considerations that can influence the efficiency of these practices (such as Ambrozi et al., 2020; Bastos et al., 2025, Goedert et al., 2025; Goeldner et al., 2020; Klaumann et al., 2025; Marcos et al., 2025; Milkievicz et al., 2025; Pokriwieski et al., 2025; Radzinski et al. 2025; Schwarzer et al., 2025, and Teixeira et al., 2025).

Citing technological advances, fluorescent lamps, created by Nikola Tesla, have emerged as a more economical and efficient alternative compared to their predecessors, incandescent lamps. However, as they have mercury in their structure, a heavy metal highly harmful to the environment and to humans, its incorrect disposal ends up generating a huge environmental liability. For Almeida (2013), in this context, with the increasing generation of solid waste, and the recent search for alternatives for a correct disposal, as well as its management, have become mandatory actions.

Changes in habits, both productive and consumerist, due to pressure from society, environmental protection organizations and even the market, are observed as an attempt to adapt the activities of corporations to this new reality. Thus, some guidelines have been used to change the fate of solid waste. One of them is the 5 R (Rethink, Reuse, Reject, Reduce and Recycle), a policy that aims to reduce the generation of waste on our planet. There is also reverse logistics, and their agreements already implemented, one of which is the Fluorescent Lamps of sodium and mercury vapor and mixed light. In Reverse Logistics, corporations need to take responsibility for the waste generated as well as for the life cycle of products (Akatu Institute, 2010).

As it is a concept considered relatively new, its full operation depends on more maturity (knowledge and awareness) of the various people involved, because, according to Fagundes (2015), the National Policy on Solid Waste - Federal Law 12.305/2010 (Brazil, 2010) - basis for Reverse Logistics systems, society as a whole plays a fundamental role in waste management, thus creating a chain of responsibilities, the so-called Shared Responsibility.

The difficulty in determining the amounts of sodium and mercury vapor fluorescent lamps and post-consumer mixed light, as well as the attempt to identify what would be the main factors that may influence the correct destination of this material by small generators (individuals) through Reverse Logistics, becomes the justification for this research.

2 THEORETICAL FRAMEWORK

This chapter presents studies on the fluorescent lamp, mercury (Hg), heavy metal and main contaminant contained in the lamp, the National Solid Waste Policy - PNRS - (Brazil, 2010) and the Solid Waste Policy in the city object of this research, São Bento do Sul, state of Santa Catarina, Brazil.

2.1 FLUORESCENT LAMPS

With the constant need to innovate technologically and energetically, fluorescent lamps have replaced incandescent ones because they are more economical and have a longer life span (Ecycle, 2025a; Foxlux, 2025)

Fluorescent lamps are divided into compact and tubular lamps. The compact ones are divided into integrated reactors, having the reactor inside the lamp body, and not integrated, having the reactor outside the lamp, requiring a separate reactor installation. Tubular are divided into four main formats, T12 (38mm), T10 (33mm), T8 (26mm) and T5 (16mm), T8 and T5 being the most modern, because the smaller the diameter the better the light reproduced (Procel, 2011).

Both compact and tubular fluorescent lamps are composed of mercury-filled glass and inert gases that do not react with mercury, plastic or metal socket that ensures the lamp holder and provides the electrical connectors and phosphorous dust composed of Aluminum, Antimony, Barium, Cadmium, Calcium, Lead, Copper, Chromium, Iron, Magnesium, Manganese, Mercury, Nickel, Sodium and Zinc (Apliquim Brasil Recicle, 2018; Brasil Recicle, 2018).

Because they contain many toxic substances in their composition, the incorrect disposal of fluorescent lamps or even their breakdown by the population, can cause not only risks to humans and animals, but also to the soil, because in addition to mercury, the lamps contain cadmium and lead in their composition - even if the levels released by the lamp are small - thinking about the millions that are discarded incorrectly, it becomes dangerous for the planet. (Brazil Recycle, 2018; Ecycle, 2025b).

Due to the blackout of 2001, where Brazilians were forced to reduce electricity costs, a process of replacing incandescent lamps with fluorescent ones began, thus providing a decrease of up to 80% in the light bill (Guitarrara, 2025; Nord Research, 2024).

The consumer's decision to purchase fluorescent lamps, although there is a higher cost at the time of purchase in relation to incandescent, was influenced by the fact that they have a useful life about eight times longer. Nowadays, when comparing fluorescent lamps x LED lamps, fluorescent lamps are left behind in terms of energy savings, and this new model, LED, is more economically and sustainably attractive, because, in addition to the aforementioned lower energy consumption, they have the advantage of being manufactured with non-toxic materials, not requiring a special type of recycling, as opposed to fluorescent lamps, which need special attention regarding treatment for mercury (Santos *et al.*, 2015).

2.2 FLUORESCENT LAMP LIFE CYCLE

The life cycle of products is the collection of steps necessary to fulfill the functions. It begins with the extraction and processing of the raw material and continues until its final disposal. The knowledge of this factor becomes of great value for Life Cycle Analysis (LCA), thus contributing to the reduction of environmental impacts, in addition to making it possible to analyze several products of the same segment, which contributes to the reduction of consumption, pollution and environmental damage (Ecycle, 2025c; Abnt, 2009; Ribeiro, 2010).

After use, there are five different ways for the recycling process of fluorescent lamps in Brazil: Blow treatment, simple, thermal and chemical milling, and solidification / encapsulation. The safest and most effective process, and consequently the most used in Brazil, is the thermal grinding (Bacila, 2012; Bacila *et al.*, 2014; Brandão *et al.*, 2011; Mombach *et al.*, 2008; Mourão, Seo, 2012; Polanco, 2007).

Also, according to the same authors, after recycling, the materials (solid waste) extracted are: plastic base, glass, decontaminated phosphoric powder, brass, aluminum and liquid mercury. For the generation of 1 kg of glass, four to six lamps are needed, for 1 kg of sockets (from which brass and aluminum are extracted) approximately 350 lamps are needed, for 1 kg of phosphoric powder approximately 110 lamps are needed and for the generation of 1 kg of mercury (Hg), approximately 50,000 lamps are needed. The glass obtained in the process can be used in the manufacture of glazed finish for ceramics, the sockets are revitalized in the metallurgical industries such as brass and aluminum, the phosphoric powder can be used in some processes in the industries of the ceramic sector and finally the mercury (hg), after processed, can be used in

the manufacture of thermometers, fractional use and for dental use (recycler).

2.2.1 Mercury and the consequences of improper disposal of Fluorescent Lamps

Found naturally in the environment, the element mercury (Hg) can be located in many places in the world (Unep, 2013). According to Azevedo (2003), "mercury (Hg) is a heavy metal that under normal conditions of temperature and pressure is shaped like a silver liquid."

Abstract: Mercury, in its metallic form, is customarily destined to the production of chlorine-soda, non-electronic instruments, utensils for medical, surgical, dental, gold amalgamation and for the production of lamps (Ibama, 2012). The mercury extracted during the recycling process of the lamps, however, can be reused in the manufacture of new lamps, thermometers, manometers, among others (Avant, 2013).

Because it is a heavy and toxic metal, if this material was discarded incorrectly, it can cause great damage not only to the environment, but also to human health.

2.2.2 Human Exposure to Mercury

According to Silva (2005), it is important to note that despite the small amount of mercury (Hg) contained in a single lamp, incorrect disposal of a large volume of this material maximizes this factor. Also according to Silva (2005), the human being to have contact with mercury, can present intoxication frame with the following symptoms: depression, panic syndrome, fatigue, tremors, difficulty in speech, motor uncontrol, stomatitis, lateral walking, memory loss, loose teeth, loss of sexual performance, pain and paralysis of the extremities. Mercury can still cause other disorders when inhaled, such as damage to the nervous system, digestive system, immune system, lungs and kidneys (Who, 2007). It is very worrying, because the effects can be irrecoverable.

According to the World Health Organization (WHO), the tolerance for exposure to mercury vapor inhalation is 0.2 μg/m³. The limit set for air is 1 μg/m³, for water it is 1 μg/L of total mercury and for intake it is 2 μg/kg body weight per day (Who, 2007).

Mercury (Hg), when found in aquatic environments, becomes its most dangerous and fatal form, methylmercury (MeHg). The great danger for humans is that mercury accumulates in the inhabitants of this environment, such as fish, and thus accumulates in the food chain (CDC,

2009). Humans also become exposed to the consumption (ingestion) of untreated water. Mercury in methylmercury state can be found in both fresh and salt water at concentrations below 0.5 μg/L (Who, 2011).

2.2.3 Mercury and the environment

According to WHO (2011), the contamination of groundwater by mercury, causes serious damage to human health and also a major environmental impact, which can cause the death of living beings inhabiting this environment.

Another problem detected is that the insertion of mercury into the air occurs naturally and continuously, that is, they do not depend only on the influence of the human being in their process. Volcanic and geothermal activities, for example, also generate mercury and release it into the environment. Some studies suggest that 10% of the mercury emitted and reemitted into the atmosphere comes from natural sources (Unep, 2013).

The release of 1 mg of mercury in a 500 m³ place without ventilation is enough to exceed by up to 10 times the recommended limit (Johnson *et al.*, 2008).

The proliferation of mercury in the soil can vary according to some factors, such as redox potential, pH, soil type, among others, and can be absorbed by different types of humates and minerals (Azevedo *et al.*, 2003).

2.2.4 National Solid Waste Policy - PNRS

The National Policy on Solid Waste (PNRS), brings together a series of objectives, principles, tools, guidelines, goals and actions to be taken by the Federal Government, both in isolation, or even through partnerships with other government units, and even private institutions (Brazil, 2010).

The PNRS, or Law No. 12,305 / 10 (Brazil, 2010), puts into debate Reverse Logistics and Shared Responsibility, innovative and responsible for the entire life cycle of products, then giving the possibility of establishing new concepts and breaking certain paradigms existing in the traditional linear chain production cycle. These innovative concepts are a worldwide trend, forming cyclical chains, when the end of the useful life of a given product can generate an

opportunity for a new beginning.

According to Faria (2012), as a consequence of this rupture of model, the competitiveness and environmental responsibility of companies can increase, through the process of reuse of waste caused by the production chain, while considering secondary markets.

Article 33 of the PNRS provides for the mandatory implementation of reverse logistics by those responsible for the import, manufacture, marketing and distribution of products such as fluorescent lamps, batteries, batteries, oils, tires, electronics and pesticides, the so-called Sectorial Agreements (Brazil, 2010).

2.2.5 Reverse Logistics System with Sector Understanding for Fluorescent Lamps

The agreement regarding the implementation of the Reverse Logistics System of Fluorescent Lamps of Sodium and Mercury Steam and Mixed Light, was signed on November 27, 2014, and was published in the Official Gazette of the Union (D.O.U) on March 12, 2015 (Abilux, 2015).

The agreement aims to establish rules for the entire process of environmentally correct disposal of lamps, following the precepts of Law No. 12,305 / 2010 (Brazil, 2010), and contemplates low or high pressure discharge lamps containing mercury, such as compact and tubular fluorescent, mixed light, mercury steam, sodium steam, metal steam and special application lamps, not contemplating LED lamps because they have a different construction structure, not releasing toxic materials that harm the environment (Sinir, 2018).

With the agreement, shared responsibility for the life cycle of lamps was instituted. According to article 3, item XVII of the PNRS, responsibilities should be shared between consumers, traders, distributors, manufacturers, importers and holders of public services for urban cleaning and solid waste management, aiming to minimize the impacts on health and environmental quality, which result from the life cycle of products (MMA, 2014).

According to Moraes (2006) in this sectoral agreement, the consumer, when returning the unusable lamps at some point of collection, becomes a collaborator of the system, in addition to acting as a supervisor when charging commercial establishments that accept the return of used lamps.

This system is basically formed by two delivery networks, *B2B* (*Business to Business*),

or large generators, and *B2C* (*Business to Commerce*), called small generators, or home generators. This research has its scope focused on small generators. The flow to this network is carried out as follows: the home generator delivers the lamps at the collection points, which at first will be located in retail stores, companies, public places, among others. These places should have their own equipment for the purpose of temporary storage of lamps that no longer work (Sinir, 2014).

When the capacity of the containers is exhausted, those responsible for the collection station will request the removal and replacement of the containers. The company contracted for the collection and transport service will also be responsible for issuing the document proving the volume of material collected, and transporting the material to a company specialized in carrying out the first stage of the recycling process, performing the dismantling and classification of the component materials of the lamps, leading to the production cycle the usable material, and giving correct environmental destination to the part without conditions of recycling (Sinir, 2014).

> The definition of fixed delivery stations will follow the following prerequisites: population density of at least 250 inhabitants per km², in municipalities with more than 25,000 inhabitants, with an average distance of 4 km between each residence served. For regions that do not meet these requirements, another receiving and / or collection system must be created (Sinir, 2014a).

According to Annex I of the sectoral agreement "Forecast of municipalities with delivery points and estimated number of containers" that shows the delivery points of the *B2C* network in the first year of implementation, 35 municipalities will be added and in the following year 46 will be added to the number of municipalities served, tending to increase annually according to population density (Sinir, 2014b). One of the biggest problems that this system faces for its correct operation is precisely the fact that most Brazilian municipalities do not fit the prerequisites defined for the implementation of fixed delivery stations.

The final implementation of this agreement provides for progressive targets. It was defined that from the signing of the agreement, the signatories would have five years to reach the volume of 20% of the lamps inserted in the national market, considering the base year of 2012, receiving them and giving environmentally adequate final destination (Sinir, 2014).

2.2.6 Solid waste policy of São Bento do Sul - Santa Catarina

The city of São Bento do Sul, located in the northern plateau of the state of Santa Catarina, Brazil, instituted in 2015 its Integrated Municipal Plan for Basic Sanitation through Law No. 3629/2015, which, among other items, contemplates urban cleaning and solid waste management (Pmgirs-Sbs, 2015).

The plan, as stated in its presentation, includes:

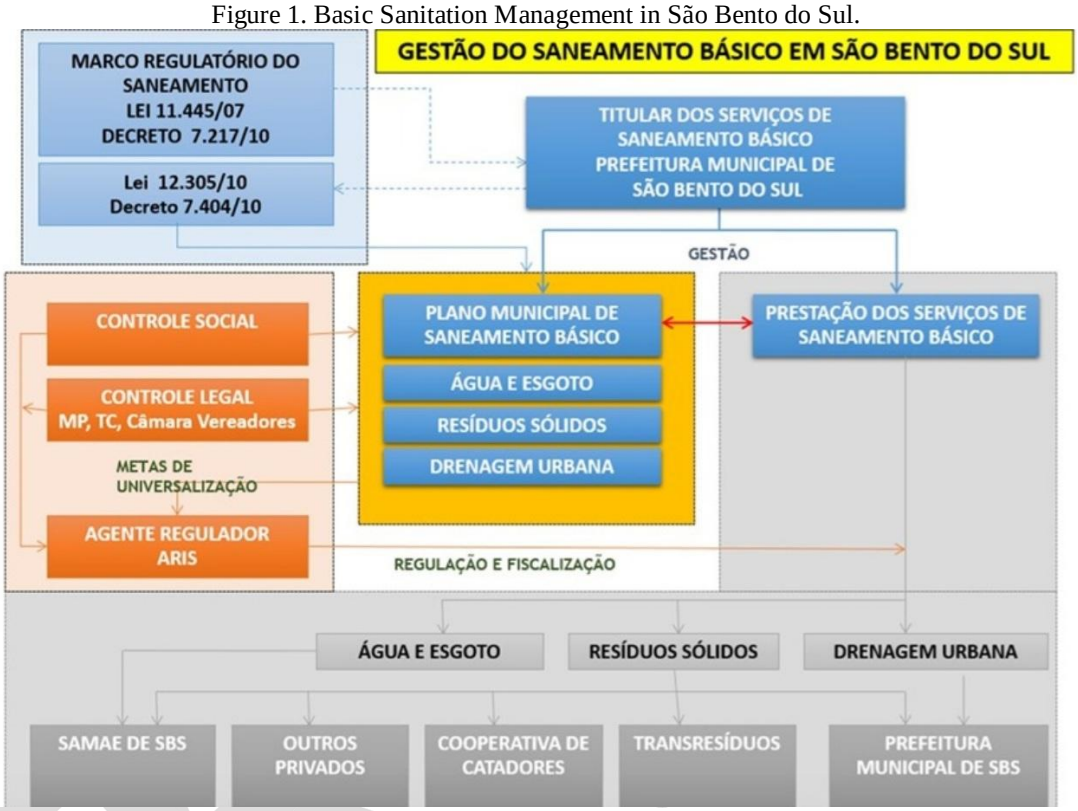
> A consolidation of the Sectoral Plans for Water Supply, Sanitary Sewage, Drainage and Rainwater Management and Urban Cleaning and Solid Waste Management, elaborated in accordance with the guidelines established in Article 19 of Federal Law No. 11.445/07, which establishes the national guidelines for Basic Sanitation and its regulatory Decree 7.217/10 and Decree 8.211/2014 and Municipal Law 3055/12 establishing the Municipal Policy of Basic Sanitation of São Bento do Sul (Pmgirs-Sbs, 2015, p.1).

It should be noted that this planning was elaborated contemplating a horizon of 20 years (2016-2035). In its Annex 3, it is included the full Municipal Plan of Integrated Solid Waste Management - PMGIRS of the Municipality of São Bento do Sul, which was elaborated in the year 2014:

> According to the provisions of the National Policy on Solid Waste - PNRS, created by Law No. 12,305, of August 2, 2010 and regulated by its Decree No. 7,404 of December 23, 2010, in addition to Article 19 of the National Basic Sanitation Policy - PNSB, Law No. 11,445 of January 5, 2007, regulated by its Decree No. 7,217 of June 21, 2010 (Pmgirs-Sbs, 2015, p.6).

The Basic Sanitation structure in São Bento do Sul, as shown in Figure 1, is composed of the Municipality of São Bento do Sul and the Autonomous Municipal Service of Water and Sewage (SAMAE), which, in addition to being responsible for the provision of water supply and sanitation services, has, since 2014, also been responsible for the management of collection, transport and final disposal of household waste, health services and construction (Pmgirs-Sbs, 2015).

Figure 1. Basic Sanitation Management in São Bento do Sul.



Source: Integrated Municipal Plan of Basic Sanitation of São Bento do Sul, 2015.

Currently, the city itself carries out and pays for the provision of public cleaning service in the city. Regular and selective home collections, transportation and final destination of waste, are being carried out by an outsourced company, in a contract supported by Law 8666/93, for an annual term, with the possibility of renewal in up to five years.

The Integrated Municipal Plan of Basic Sanitation of São Bento do Sul deals in its item 4.2.10 on the Special Waste and Reverse Logistics forecast, thus including fluorescent lamps, emphasizing that: Federal Law No. 12,305 / 10 (Brazil, 2010) in its article 33, defines that manufacturers, importers and traders will be responsible and should structure and put into practice reverse logistics systems, observing from the collection and transport of products after use by the consumer to the final disposal, thus performing an independent service of the already carried out public service of urban cleaning and solid waste management; already the State Law No. 11,347 / 2000 (Santa Catarina, 200), it also establishes standards and actions for the collection, transport and final disposal of waste considered potentially hazardous, among which can be highlighted, batteries and lamps, emphasizing the prohibition of the final disposal of these materials in landfills (Pmgirs-Sbs, 2015).

In 2018, SAMAE implemented in the city a collection station for items with reverse

logistics forecast, LEV (Voluntary Delivery Site), thus assuming part of the system process, from receiving, storing to the correct destination of the material (fluorescent lamps) of small generators (residential consumers) in the city.

3 METHODOLOGY

The basic research of this work began with the search of the literature, researching in the CAPES periodical portal and in the Scopus database, scientific articles for the formation of the theoretical reference. With the reading and identification of gaps based on questions and hypotheses, it was decided to elaborate a research to identify factors of influence on the return of sodium and mercury Fluorescent Steam Lamps and post-use mixed light, through reverse logistics in the city of São Bento do Sul, state of Santa Catarina.

The research was then put into practice in three stages: In the first stage a survey research was developed, with a questionnaire for profile analysis, behavior and consumption, targeting small waste generators or residential consumers. In order to collect data from a specific audience and analyze their behavior, to then verify the validation of the gap on what would be the main reasons for influencing the return of the amount of fluorescent lamps through reverse logistics and, at the end, to account for the results, generating graphs for the appropriate analyzes.

The execution and data collection took place in August 2020, in which one hundred and seventy-four (174) responses were obtained, all of which were voluntarily answered by digital media through the Google® Forms tool.

The second stage, in a descriptive way, was carried out in person in lamp shops in the city of São Bento do Sul, with the objective of identifying which of them receive unserviceable or post-use lamps, and also what the reasons for non-receipt. By sampling, 12 commercial establishments were interviewed, and after, the results were counted to carry out the analyzes.

And the third stage, was through an interview with the Head of the Division of Municipal Solid Waste SAMAE of São Bento do Sul, in order to understand the operation of the service offered by the municipality for the receipt and storage of unserviceable fluorescent lamps in the city.

4 RESULTS

The following are the results of the research, profile analysis and consumption of the target audience, with possible identification of the factors that can influence the correct disposal of the material, as well as the trends presented.

4.1 PROFILE OF RESPONDENTS

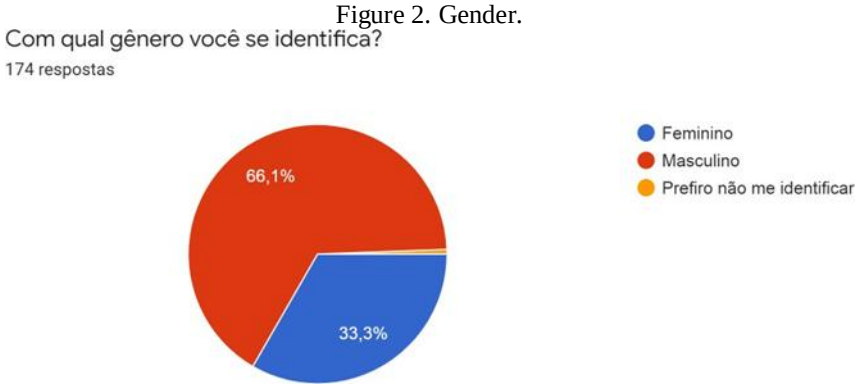
The distribution of the forms for research was carried out randomly, without considering a specific niche determined, to obtain a broader and less biased result possible. With the answers (one hundred and seventy-four), the following profile of the people interviewed can be defined, according to analyzes and respective graphs presented sequentially.

4.1.1 Characterization profile of respondents (gender, age, income, education, place of residence)

66% of respondents identify with males (Figure 2) and 43% are aged between 26 and 40 years (Figure 3), therefore categorized as generation Y (SBcoaching, 2019).

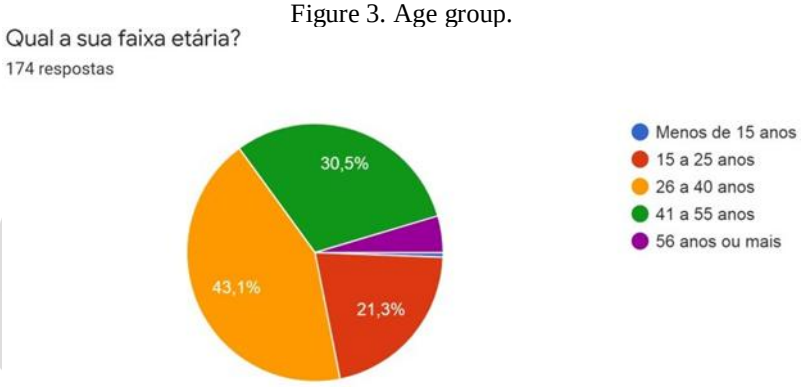
This can be considered a relevant factor, because studies indicate that the consumption patterns of generations Y and Z are very different from the patterns of generations X and Baby Boomer (Bridge Research, 2009). Generations Y and Z, that is, individuals under 40 years of age, tend to have greater socio-environmental awareness, and are adept at companies that also express these values. As the research indicates that about 64% of the interviewees belong to these generations, Y and Z, one can indicate a tendency towards a correct disposal of fluorescent lamps and a concern for consumption with products that harm the environment less.

Figure 2. Gender.



Source: Prepared by the authors themselves.

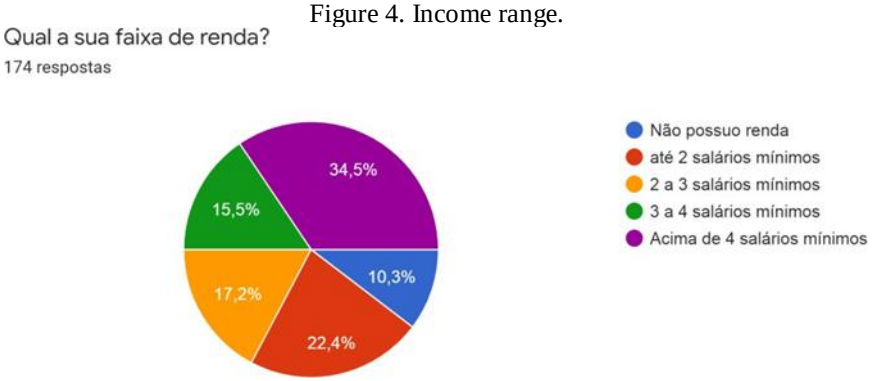
Figure 3. Age group.



Source: Prepared by the authors themselves.

When analyzing the income range (Figure 4), the research shows us a well-diversified public, only a slight concentration (34%), claiming to receive more than four minimum wages / month.

Figure 4. Income range.

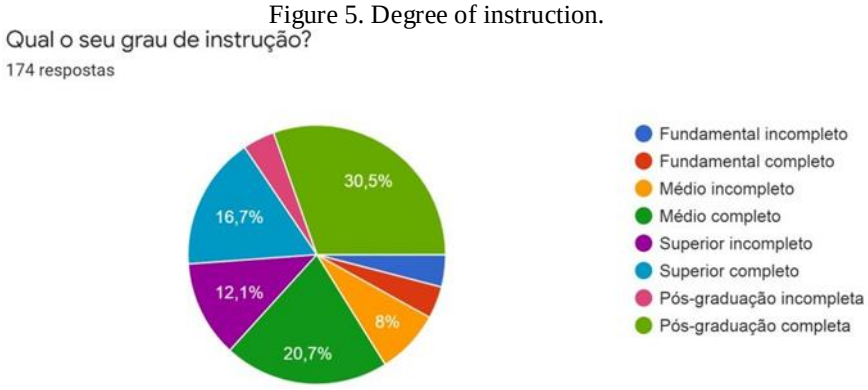


Source: Prepared by the authors themselves.

Considering the level of education (Figure 5), it is noteworthy that about 60% of the respondents claim to have a higher level, of which 34% have completed graduate school, while

another 20% of the respondents have only high school. This would be another factor that can be considered as a tendency to disposal, with environmentally correct concepts and adherence to reverse logistics.

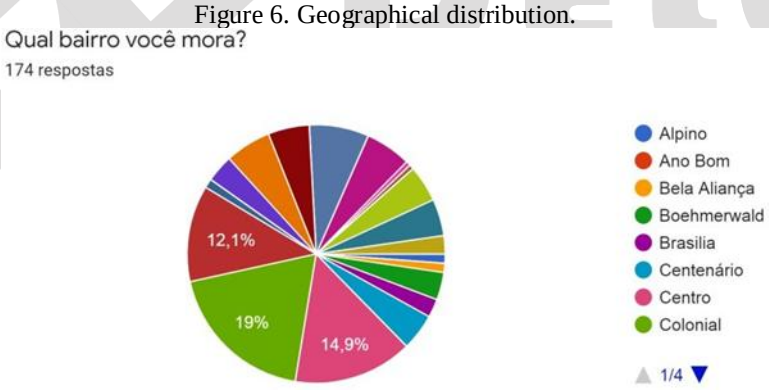
Figure 5. Degree of instruction.



Source: Prepared by the authors themselves.

The research also presents a good geographical distribution (Figure 6), considering the respondents' housing, with a slight concentration in the neighborhoods: Centro, Colonial and Cruzeiro.

Figure 6. Geographical distribution.

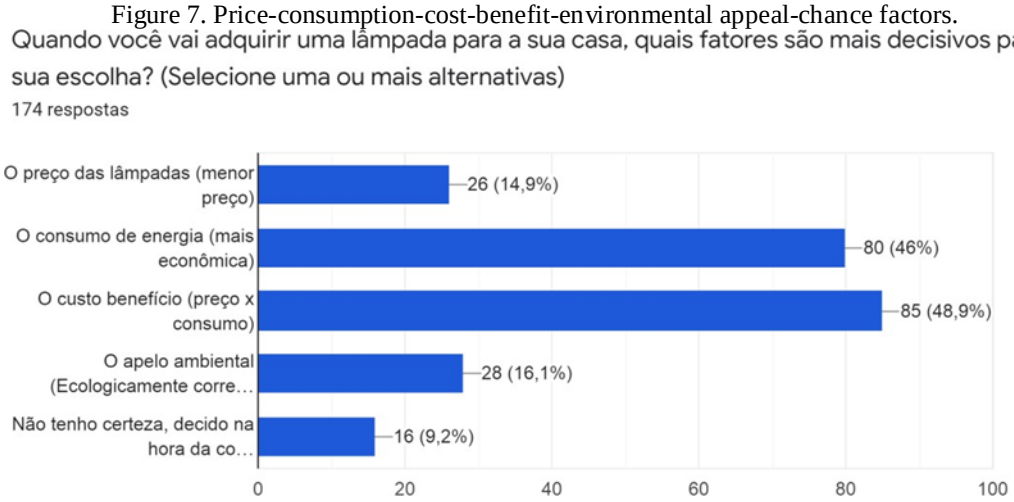


Source: Prepared by the authors themselves.

4.1.2 Consumption profile of respondents (decisive factors for purchase)

After identifying the profile of the interviewees, they were asked: "When are you going to buy a lamp for your house, which factors are the most decisive for your choice?" presenting, in sequence, some suggestions for answers, which the respondents could select as many as they deemed necessary. Figures 7 shows the results.

Figure 7. Price-consumption-cost-benefit-environmental appeal-chance factors.

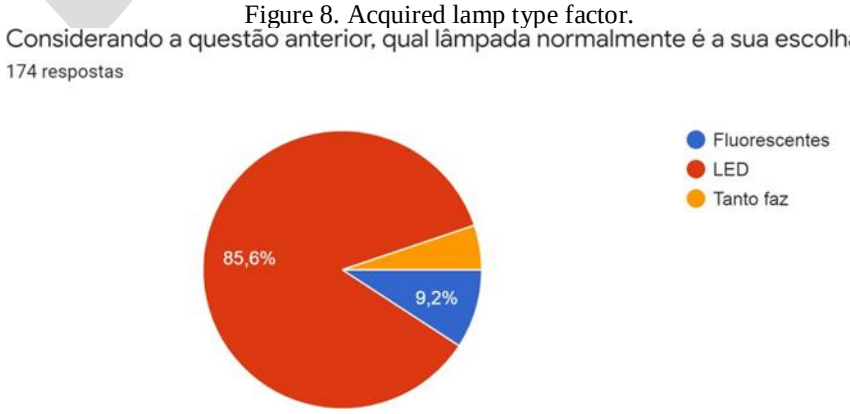


Source: Prepared by the authors themselves.

It can thus be concluded that most respondents, when choosing their lamp, opt for the economy. 46% of the responses indicate the most economical option, which consumes less energy and 48% make a broader analysis, considering cost x benefit. This factor is very relevant because it indicates a strong tendency to purchase LED lamps, which meet the cost-benefit ratio cited in the responses.

This trend is confirmed in the following question (Figure 8), when respondents were asked: "Considering the previous question, which lamp is usually your choice?"

Figure 8. Acquired lamp type factor.



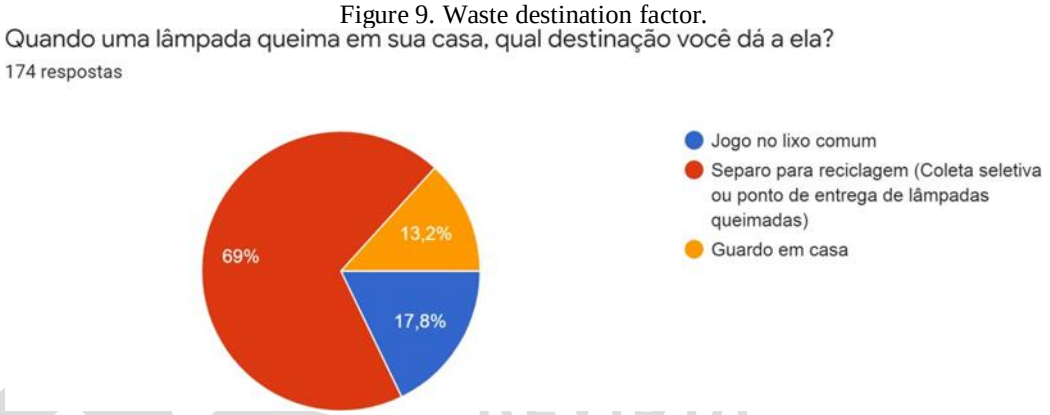
Source: Prepared by the authors themselves.

The absolute majority, 85%, opt for LED lamps, which indicates a strong tendency to purchase this product.

4.1.3 Environmental awareness profile of the interviewees (motivating factors for the choice of destination)

In the next tab of the research, some questions were formulated regarding the disposal of unserviceable lamps in the interviewees' homes. The first question was, "When a lamp burns in your house, what destination do you give it?" Figure 9 shows the results.

Figure 9. Waste destination factor.

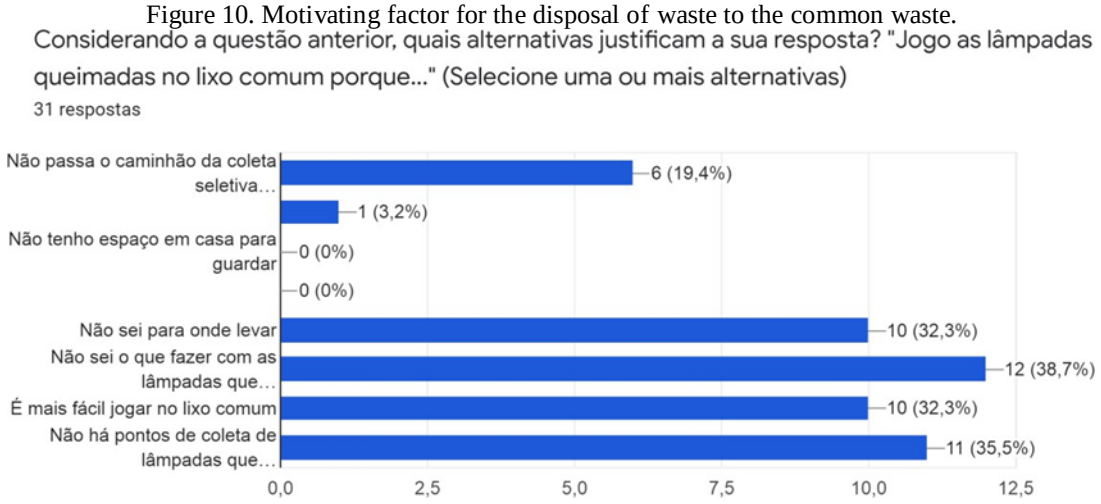


Source: Prepared by the authors themselves.

The survey found that 69% of respondents said that when the lamps in their home no longer work, they separate for recycling or take it to a delivery point. This result also points to a positive trend, in relation to socio-environmental awareness. It is relevant to note that the survey still indicates a high percentage (31%) of people who still throw the lamp in the common garbage or even keep it in their homes.

According to the answer to the previous question, the interviewee was directed to a new question, and then provided data to justify the reasons that led him to answer the previous question. Considering the question: "I throw the burnt lamps in the common garbage because…" the answers contained in Figures 10, 11 and 12 were obtained.

Figure 10. Motivating factor for the disposal of waste to the common waste.

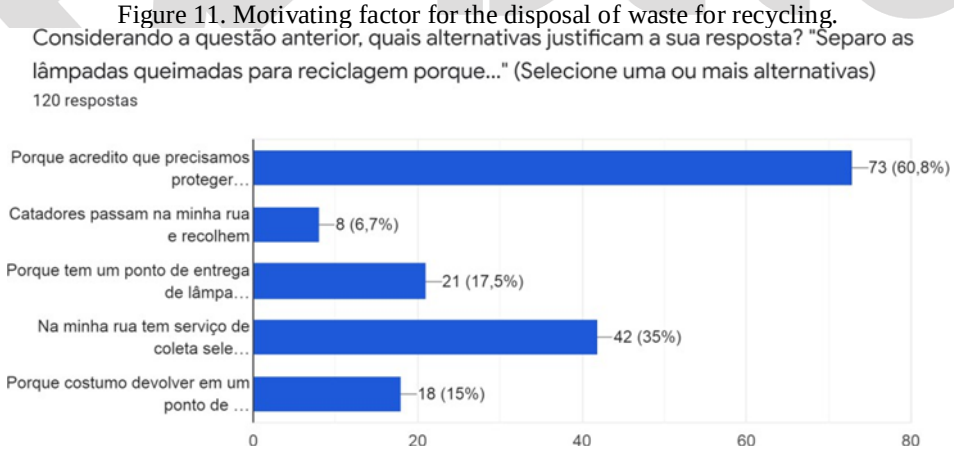


Source: Prepared by the authors themselves.

Figure 10 shows that 35% report that there are no collection points near their residence and 32% because it is easier to dispose of in the common garbage. But the trend points out that the main reason, with approximately 70% of the responses, is due to the lack of knowledge of the user, how to proceed when a lamp becomes unserviceable.

For the interviewees who answered "I separate the burnt lamps for recycling because…?" Figure 11 indicates the justifications of the respondents to the questionnaire.

Figure 11. Motivating factor for the disposal of waste for recycling.



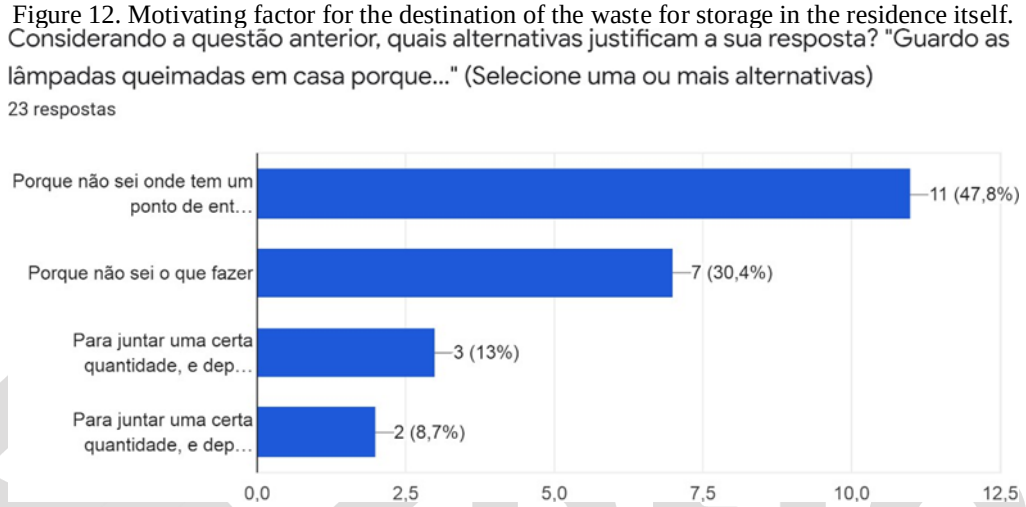
Source: Prepared by the authors themselves.

The survey confirms a trend towards environmental awareness, showing that 60 per cent of respondents say they act this way because they believe they need to protect the environment. Despite the positive results, one item draws attention, the 35% of the answers that state that they discard because there is a selective collection service on their street. The answer even shows

concern with the correct mode of disposal, however, the selective collection service does not collect fluorescent lamps. The correct disposal must be at the Voluntary Delivery Site (LEV), which will be explained below. This item also points to a lack of knowledge on the part of the interviewees.

For the interviewees who answered "I keep the burnt lamps at home because…?" Figure 12 indicates the justifications of the respondents to the questionnaire.

Figure 12. Motivating factor for the destination of the waste for storage in the residence itself.



Source: Prepared by the authors themselves.

Once again the main reason pointed out (approximately 77%) indicates that the respondents do not know exactly what the correct process for discarding the lamps that no longer serve.

With the analysis of the data, it is concluded that there is a tendency of the respondents to abandon the consumption of fluorescent lamps, adhering to the LED lamps, which demonstrate a better cost x benefit, besides a more coherent environmental appeal. Most respondents, according to this research, usually direct the unserviceable lamps for proper disposal. The objective of identifying possible factors of influence for the return of the unserviceable lamps, indicates that the lack of information is still one of the main reasons for the erroneous direction of these residues, either for not knowing where to direct the material, or even for not knowing what to do with it.

4.2 COLLECTION POINTS

In the second stage of this research, 12 lamp trades in the city of São Bento do Sul were interviewed in person and randomly. These trades are located in the following neighborhoods:

Shops 1 to 5 - Centro

Shops 6 and 7 - Rio Negro

Store 8 - Centenary

Shops 9 and 10 - Boehmerwald

Shop 11 - Serra Alta

Shop 12 - Colonial

The following questions were briefly asked:

A) "I have a burned-out fluorescent lamp and would like to deliver it for disposal. Do you receive this material?"

Of the interviewees, 08 stated categorically that they do not receive, another 02 gave the option of receiving if a new material was acquired and another 02 stated that they only receive material from large generators (Legal Entity).

B) So then he was asked, "Why don't they receive it?"

The same 08 who had answered that they did not receive, also did not know the reasons. The other 04 respondents stated that the costs for the reception and the correct disposal of the lamps is high, not compensating for the store to offer the service.

With this analysis, it is concluded that the local commerce of São Bento do Sul, does not offer the service of return of fluorescent lamps to small generators.

4.3 SAMAE INTERVIEW

As reported in item 2.3.2 of this article, one of the possible difficulties for the implementation of the agreement is that the definition of fixed delivery stations should have as prerequisites:

> Population density of at least 250 inhabitants per km², in municipalities with more than 25,000 inhabitants, with an average distance of 4 km between each residence served. For regions that do not meet these requirements, another receiving and / or collection system must be created (Sinir, 2014a).

Most Brazilian municipalities do not fit this question, including São Bento do Sul, and should then, according to SINIR, create another system of receiving and / or collection. It was then that, from the definition of the Solid Waste Policy of São Bento do Sul, in 2015, SAMAE - Municipal Autonomous Service of Water and Sewage, defined its performance in relation to Reverse Logistics and PNRS.

In 2018, it created the LEV (Voluntary Delivery Site), a point that receives solid waste that cannot be disposed of along with recyclable waste, such as fluorescent lamps, and thus also proceed with the correct disposal of such waste. At this stage of the research, an interview was conducted with the head of the Division of Municipal Solid Waste of the municipality, in order to support the operation of the LEV regarding the fluorescent lamp system. With the consent of the interviewee, the content of the interview is described below.

- On what date was the LEV (Voluntary Delivery Place) inaugurated in São Bento do Sul?

Answer: *The LEV was inaugurated in mid-2018*.

- How has Samae perceived the demand of the population for the return of fluorescent lamps? Is the demand big or shy?

Answer: *The demand for disposal is great. We receive around 30,000 light bulbs/year*.

- Does the LEV receive only material coming from an Individual or from a Legal Entity as well? Shopkeepers who also receive return of lamps, can forward to the LEV?

Answer: *The LEV receives only from small generators, that is, Physical Person, for large generators (Legal Entity and Shopkeepers) the responsibility for destination is the generator itself.*

- The material that reaches the LEV, it is only Fluorescent Lamps or the population ends up taking other types of lamps too (LED, etc.)? If yes (other types), do you have any idea of the quantity?

Answer: *All kinds of bulbs can be taken to LEV, we have received many LED bulbs. The total received in the last 2 years was 30,000 lamps/year*.

- I noticed that the material is stored in a container. But after that, how does the process work? Where is the material intended for? Does Samae sell to any specialized company, or is there an agreement for recycling?

Answer: *The material is temporarily stored in a container, and when it is almost full,*

SAMAE hires the appropriate destination, that is, a company that does the decontamination and recycling of the material.

- Is it possible to identify if the population still discards lamps in the common garbage? Or in selective collection? Are the lamps that end up going to selective collection, afterwards destined for the LEV?

Answer: *Yes, there is still disposal of lamps in the ordinary garbage, as well as amid the recyclable material that arrives in the cooperative, in the latter case, the material is separated and taken to the LEV.*

- Is there a control of the number of lamps that reach the LEV, given year by year for example? If so, is it possible to share this statistic? (remembering that the data provided will be used only for academic purposes, in the preparation of the scientific article).

Answer: *In 2018, 50,000 lamps were destined, and in 2019, 55,000 lamps*.

- Still with regard to the indices, the PNRS establishes some (general) goals for the agreement of this system, such as a target of 20% return of lamps from the total placed on the market in 2012. Does Samae have any specific goals?

Answer: *The Municipal Plan for Integrated Solid Waste Management (Law No. 3629/2015), does not establish destination targets, even because the responsibility must be the manufacturers, however, as the reverse logistics of lamps has not yet been fully* implemented, the municipal government decided to bear the costs and implement this system, aiming at the reduction of contaminating material in the Municipal Landfill.

After the interview, a visit was made to the LEV site to verify its functioning, and the images presented in Figures 13 to 16 were recorded.

Figure 13. Voluntary Delivery Place (LEV) in São Bento do Sul/SC.

Source: Prepared by the authors themselves.

Figure 14. Voluntary Delivery Place (LEV) in São Bento do Sul/SC.

Source: Prepared by the authors themselves.

Figure 15. Voluntary Delivery Place (LEV) in São Bento do Sul/SC.

Source: Prepared by the authors themselves.

Figure 16. Voluntary Delivery Place (LEV) in São Bento do Sul/SC.

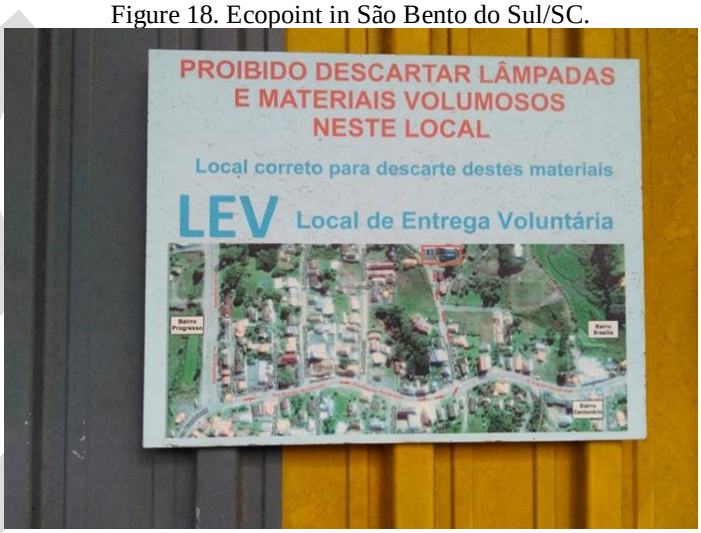
Source: Prepared by the authors themselves.

When observing the Ecopoints of the city of São Bento do Sul / SC (Figure 17), a signaling on the disposal of bulbs and bulky materials was noticed, guiding the population to dispose of these materials at the Voluntary Delivery Site (LEV), with indication of the location of the LEV through an aerial image of the city (Figure 18).

Figure 17. Ecopoint in São Bento do Sul/SC.

Source: Prepared by the authors themselves.

Figure 18. Ecopoint in São Bento do Sul/SC.



Source: Prepared by the authors themselves.

Through internet searches on LEV in São Bento do Sul/SC, little information was found. At the time, the SAMAE and City Hall websites did not provide specific information. It was concluded that further dissemination of this excellent initiative was needed.

5 ANALYSES AND DISCUSSIONS

Based on the results of the research, performing a joint analysis of the three stages, it can be identified that the main factor of influence regarding the return quantities of fluorescent lamps is the lack of knowledge of the population in relation to the correct disposal procedures and reverse logistics. However, it is also possible to identify that the city has excellent indexes regarding the environmentally correct disposal of solid waste.

To achieve even better indexes, one can suggest greater disclosure regarding LEV (Voluntary Delivery Site), in view of the lack of information on the responsible municipality's own website; a campaign for dissemination with the population would be another pertinent suggestion.

Another important factor to consider, identified in the research related to small generators and also in the interview with SAMAE, is the fact that the population is already acquiring more LED lamps than fluorescent ones, which in the very near future will generate a new demand, the recycling of LED lamps. LED lamps are an electronic component, but they have in their structure a large amount of plastic (bulb lamp). The current system of reverse logistics of electronic waste does not include LED technology, which may cause a new discussion and other proposals for this new liability that has been forming.

Still, it can be evidenced in the research, that the population of the city of São Bento do Sul / SC has indexes that suggest a good environmental awareness regarding the correct disposal of fluorescent lamps, as well as the conscious consumption of products with lower environmental impacts, such as LED lamps.

6 FINAL CONSIDERATIONS

Abstract: This research had as general objective to identify which factors can influence the return quantities of fluorescent lamps, sodium and mercury vapor and mixed light post-use through Reverse Logistics in the city of São Bento do Sul, Santa Catarina, Brazil.

In this way, after research and identification of gaps in the pertinent literature, the data collection (survey) was elaborated addressing small generators, a face-to-face research with shopkeepers and an interview with the responsible for the solid waste department of the city of São

Bento do Sul.

Completed the data collection, and thus carried out the appropriate analyzes, it can be concluded that the reverse logistics, through the service of return of unserviceable lamps in the city, is structured in a very adequate way.

On the factors of influence on the return of fluorescent lamps through reverse logistics, it can be inferred different motivations between the components of the reverse chain, accentuating the possibility of lack of knowledge, and that, in this sense, an educational campaign could further improve the collection rates presented.

Thus, this research brought as a contribution, in addition to the identification of influencing variables, the possible trends of consumption and disposal behavior of consumers, making it possible to obtain a conceptual basis and suggestions for the continuity of this research within the theme of reverse logistics.

Finally, envisioning future developments, this research can be used as a subsidy for further analysis and considerations within this theme.

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