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Special Edition

Assessment of disposal and recycling of waste tyres in Brazil

Avaliação da destinação e reciclagem de pneus inservíveis no Brasil

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ABSTRACT

Waste tyres discarded and accumulated in inadequate places represent a threat to the environment and public health. The problem related to the final disposal of such a solid waste occurs in every country in the world; thus, laws and standards that regulate, control, and assess solid waste management, such as waste tyres, are necessary. In Brazil, since 2009, manufacturers and importers must collect and properly dispose of a waste tyre for each new tyre sold. The National Solid Waste Policy implemented in 2010 requires tyre manufacturers, importers, distributors, and traders to implement reverse logistics systems. In this scenario, this work aims to assess the evolution of waste tyres disposal and recycling in Brazil and verify the compliance with the resolutions of Brazilian environmental agencies, also listing the main destinations. The methodology adopted consists of examining bulletins and documents from Brazilian environmental agencies between 2010 and 2019. As a result, the fulfilment of the national destination goal for the manufacturers and importers of new tyres, and the effective amount of tyres disposed of in an environmentally acceptable way, was not reached in any of the evaluated years. On the other hand, new tyre manufacturers met the target every year, while importers did not. From 2010 to 2019, the main types of disposal activities were co-processing (2,615,299 t), granulation (1,241,456 t) and lamination (495,624 t). On average, the Southeast region has the highest percentage of waste tyres disposal (57.0%), followed by the South region (23.0%), while the lowest percentage was observed in the North region (2.2%). Despite the regulations for the reuse of waste tyres, the practices adopted in Brazil cannot be considered environmentally adequate. In addition, it is important to note that the data analyzed refer to the information collected, which may not represent the total number of companies existing in the country.

Keywords: Tyres; Recycling; Destination

RESUMO

Os pneus inservíveis quando descartados ou acumulados na natureza ou em locais inadequados representam uma ameaça ao meio ambiente e à saúde pública. A problemática de disposição final de resíduos sólidos ocorre em todos os países do mundo, sendo necessárias leis e normas que regulamentem, controlem e avaliem o gerenciamento de resíduos sólidos como os pneus inservíveis. No Brasil, desde 2009, os fabricantes e importadores de pneus novos devem coletar e dar destino adequado aos pneus inservíveis. A Política Nacional de Resíduos Sólidos instituída em 2010 obriga os fabricantes, importadores, distribuidores e comerciantes de pneus a implantar sistemas de logística reversa. Neste cenário, este artigo tem como objetivo avaliar a destinação e reciclagem dos pneus inservíveis no Brasil, e verificar o efetivo cumprimento das resoluções dos órgãos ambientais brasileiros e elencar as principais destinações. A metodologia adotada consiste na análise de boletins e documentos dos órgãos ambientais brasileiros de 2010 a 2019. Como resultado, o cumprimento da meta de destinação nacional total não foi alcançado em nenhum dos anos avaliados. Por outro lado, em todos os anos os fabricantes de pneus novos cumpriram a meta, enquanto importadores não. Os principais tipos de atividades de destinação entre 2010 e 2019 foram o co-processamento (2.615.299 t), a granulação (1.241.456 t) e a laminação (495.624 t). Em média, a região sudeste possui o maior percentual de destinação de pneus inservíveis (57,0%), seguida pela região sul (23,0%), sendo o menor percentual registrado na região norte (2,2%). Apesar da regulamentação de reaproveitamento de pneus inservíveis, as práticas adotadas no Brasil não podem ser consideradas ambientalmente adequadas. Ainda, é importante observar que os dados analisados se referem às informações coletadas, que podem não representar o número total de empresas existentes no país.

Palavras-chave: Pneus; Reciclagem; Destinação

1 INTRODUCTION

More than 1.6 billion new tyres are produced every year globally, and, consequently, around 1 billion waste tyres are generated (GLOBALSTEIN, 2021). In Brazil, 40 million tyres are produced annually on average. In 2020, 67.9 million units were sold (replacement, assemblers, and exports), i.e., 6.4 million units less than in 2019 (ANIP, 2020). However, after use, waste tyres become a problem and generate environmental impacts when discarded in inappropriate places or disposed of in landfills or open dumps, which affects the population's health and quality of life. Recycling and reinsertion methodologies for solid waste are viable and cost-effective to minimize the environmental impact of waste tyres.

Proper collection and disposal of solid waste are necessary to maintain public health, safety, and environmental quality. In 2010, the National Solid Waste Policy (NSWP) was implemented through Law No. 12305, which sets

guidelines on solid waste management in Brazil. According to Article 33, tyre manufacturers, importers, distributors, and dealers must structure and implement reverse logistics systems upon return of the tyres used by the consumers, regardless of the general urban cleaning and management provided by the government (BRASIL, 2010).

Waste tyres are considered one of the most common hazardous solid wastes in the world. Without adequate management, such waste threatens the environment by contaminating surface and underground waters, and it is highly combustible and can cause fires (KORDOGHLI *et al*., 2014).

Tyres inappropriately disposed of constitute an environmental liability with risks to the environment and public health due to the difficulty in biodegradation (600 years). Besides, they can proliferate Aedes aegypti mosquitoes (which transmits dengue, *chikungunya*, and zika), and the volume generated occupies large spaces in cities (MMA, 2018).

Previous to the National Solid Waste Policy, the National Council for the Environment (CONAMA) established the waste tyres amount that manufacturers and import companies must collect and dispose of properly. According to CONAMA Resolution No. 416, of September 30, 2009, still in force, for each new tyre sold (more than 2 kg), the manufactures or import companies must provide an environmentally friendly destination for one waste tyre. Also, old tyres must be retreaded and then reused and recycled before final disposal (CONAMA, 2009).

According to the Ministry of the Environment (MMA, 2018), to comply with the National Solid Waste Policy, distributors, resellers, consignors, consumers, and public authorities must work with manufacturers and importers to implement procedures for the collection of waste tires existing in the country. Partnerships with city halls to provide temporary storage areas for waste tires are recommended to promote reverse logistics.

To comply with the National Solid Waste Policy, the Ministry of the Environment (MMA, 2018) considers that distributors, resellers, consumers, and public authorities must join manufacturers and importers to implement waste tyres collection in the country. Moreover, partnerships with city halls are recommended to provide temporary waste tyres storage areas to promote reverse logistics.

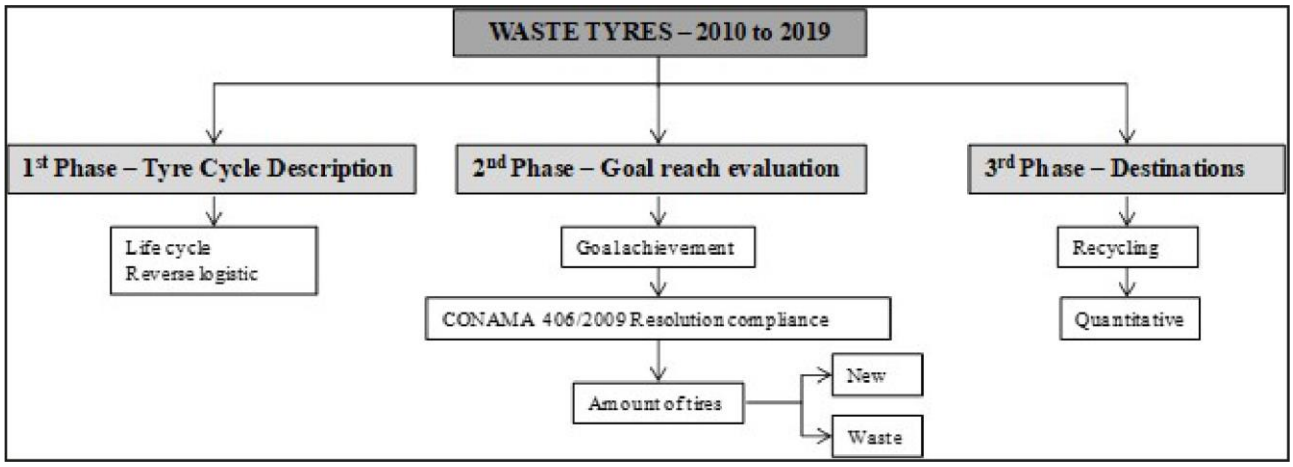
New tyres manufacturers and importers must declare, annually, to the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA) data about the proper waste tyres disposal. As stated in Normative Instruction No. 1, March 18, 2010 (IBAMA, 2010), tyre manufacturers and import companies declare the Federal Technical Registry (FTR) data. IBAMA uses the information for verifying compliance with the annual goal for the collection and disposal of waste tyres of those companies.

Considering the environmental problems caused by waste tyres placed in open dumps or inappropriate places and, after more than ten years of the National Solid Waste Policy implementation, it is necessary to assess the management of such waste in Brazil. Therefore, this work aimed to assess the evolution of waste tyres disposal and recycling in Brazil and verify the compliance with the resolutions of Brazilian environmental agencies. Additionally, the quantities of the leading waste tyres destinations in Brazil were evaluated.

2 MATERIAIS E MÉTODOS

The methodology was divided into three main phases as shown Figure 1.

Figure 1 – Flowchart of the methodology



Source: Authors, 2021

The first phase described the life cycle of tyres, including manufacture and import, maintenance, end of life, disposal and collection, disposal, and recycling products. The goal of the manufacturers and importer companies was evaluated in the second phase. Data were obtained from the annual reports of IBAMA and the Ministry of the Environment (MMA).

To assess the goal, manufacturers and importers companies initially have to register at the Federal Technical Registry (FTR), according to each category shown in Table 1, fill in two reports a year, and submit data every quarter (IBAMA, 2010). The activities follow the provisions of IBAMA Normative Instruction No. 11, corresponding to the activities of new tyres importing and waste tyres disposal (IBAMA, 2018a).

Table 1 – Categories of companies' registration in the FTR

Registration	Category	Description
Importers	Automotive vehicles and tyres	Tyres importers and similar
Manufacturers	Industry and rubber	Tyre manufacturing
Shipping company	Utility services	Disposal of waste tyres

Source: Based on IBAMA, 2018a

The first report contains activities information such as production, import, export, and shipment of tyres to new vehicle manufacturers (under position 4011 of the Commercial Nomenclature of the Common Market of the South – Mercosur) and the corresponding quantities (in kilograms and units). In the second report, information related to the implemented collection points is registered. Shipping companies must inform the registration of the benefited company (manufacturer or importer) and the destination of the waste (quantity in kilograms and type of process used). Through the system, IBAMA processes the data and, then, the companies can check the evolution of the destination goal and its fulfilment. The annual goal achievement was calculated using Equation (1) for manufacturers and Equation (2) for importers, in which a percentage (30%) is applied to consider a wear factor. The quantity of tyres sold in the replacement market is calculated using Equation (3).

$$\text{Goa l} = [(\text{a- b- d}) \times 0.70] \quad (1)$$

Where: a is the quantity of manufactured tyres (t), b is the quantity of exported tyres (t), d is the quantity of tyres sent to vehicle assembler (t).

$$\text{Goal} = [(\text{a- b}) \times 0.70] \quad (2)$$

Where: a is the quantity of imported tyres (t), b is the quantity of tyres sent to vehicle assembler (t).

$$\text{RM} = (\text{T+I}) - (\text{E+P0}) \quad (3)$$

Where: RM is Replacement Market, T is the quantity of produced tyres (t), I is the quantity of imported tyres (t), E is the quantity of exported tyres (t), P0 is the quantity of tyres in new vehicles (t).

Through the data obtained, compliance with the target established by CONAMA Resolution No. 416/2009 could be verified. From 2010 to 2019, the number of new and unserviceable tyres in the country was also evaluated. In the third phase, the quantities referring to the main destinations of waste tyres in terms of recycling and corresponding quantities are presented.

3 RESULTS

3.1 Tyre life cycle

CONAMA Resolution No. 416/2009 defines a tyre as the component of a tread system, which consists of elastomers, textile products, steel, and other materials that, when assembled on a vehicle wheel and containing fluid under pressure, transmit traction. Also, its adherence to the pavement surface elastically supports the vehicle load and resists the pressure caused by the ground reaction. The conceptualization adopted for the types of tyres, according to their condition, is presented in Table 2. Figure 2(a) shows, in a simplified way, the tyre life cycle and Figure 2(b), the reverse logistics cycle.

Table 2 – Tyres classification

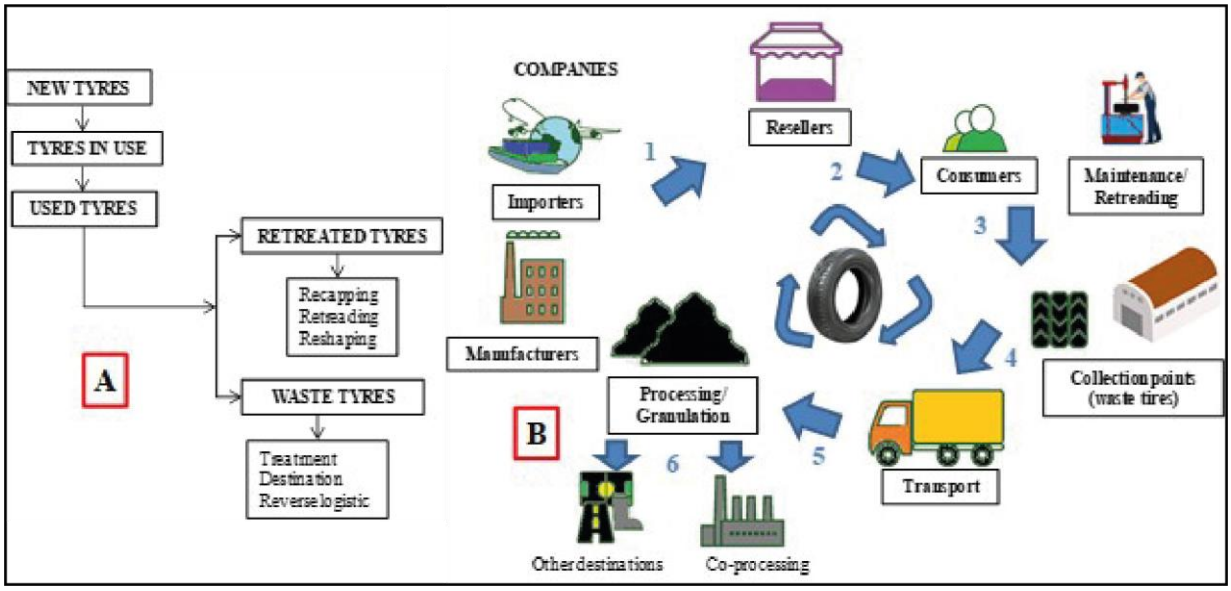
Type	Description
New	Tyre of any origin that has not undergone any use or retreading, and shows no signs of ageing or deterioration.
Used	The tyre was subjected to use and ageing. It encompasses retreading and waste.
Retreaded	The used tyre has undergone a carcass reuse process with the specific purpose of increasing its useful life. Such processes include retreading and remoulding.
Waste	The used tyre with irreparable damage to its structure without further possibility of rolling in or retreading.

Source: Based on CONAMA, 2009

According to Figure 2(a), when a new tyre is in use becomes a used tyre, it can be retreated or discarded as waste and then be allocated for recycling. The lifecycle represents the linear model (Figure 2a). The linear model, still used by many companies and industry sectors, is at its limit since the resources used in production follow a single line, that is, beginning, middle, and end, currently considered an unsustainable practice (LEITÃO, 2015; GONÇALVES *et al*. 2019). As shown in Figure 2(b), it is observed that after the life cycle, the waste tyre must be taken to the collection points and should be transported to an environmentally

suitable destination. Collection points are locations defined by tyre manufacturers and importers to receive and temporarily store waste tyres. In this case, reverse logistics encompasses a set of stages of collection and disposal of solid waste to the business sector for reuse, minimizing the environmental impact.

Figure 2 – Tyre life and reverse logistics cycles



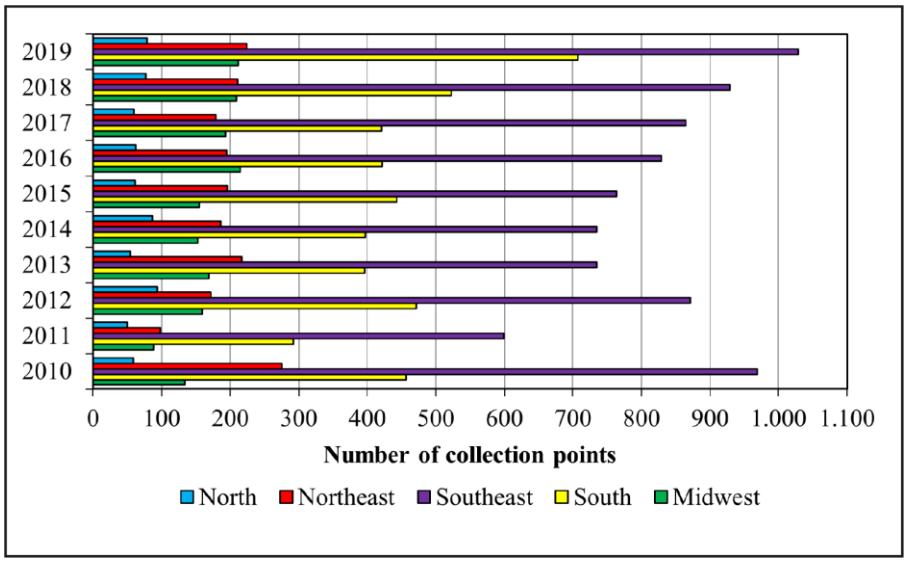
Source: Based on MMA, 2018; RECICLANIP, 2020a

CONAMA Resolution No. 416/2009 establishes that the manufacturers or importers must collect and properly dispose of an unserviceable tyre for each new tyre sold. In addition, companies must implement collection points for waste tyres in all municipalities with more than 100,000 inhabitants.

Figure 3 shows the number of collection points in each Brazilian region. In Brazil, the 2,251 collection points are distributed among the states and the Federal District. In 2019, out of which 1,256 were located in cities with more than 100,000 inhabitants. The Southeast region concentrates the most significant number of points (45.7%) and the North region the smallest, i.e., 3.5% of the total. São Paulo state has most of the collection points (609), followed by Minas Gerais state (300) and the Rio Grande do Sul state (292). It can be seen that the number of collection points increased over the period 2010−2019. From 2001 to 2020, more than 5.6

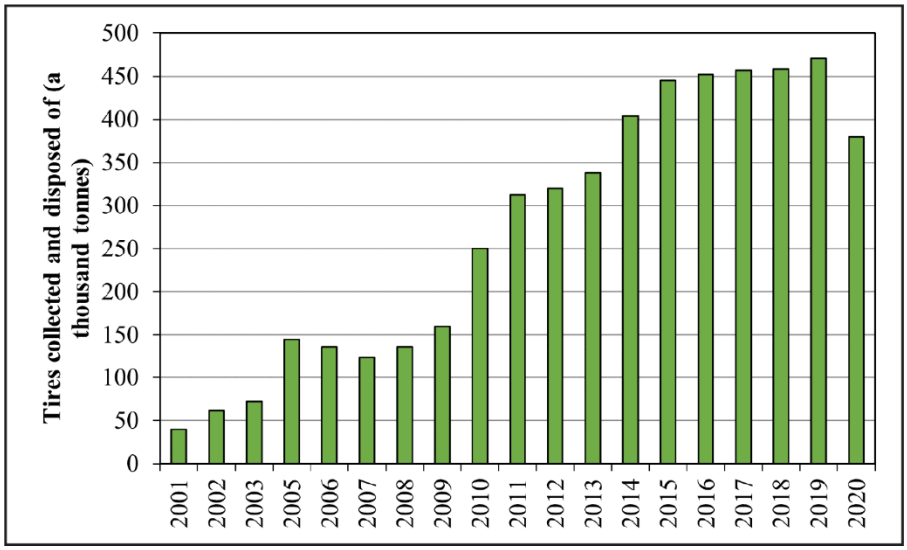
million tons of waste tyres were collected and disposed of, which is equivalent to 1.1 billion car tyres (RECICLANIP, 2020). In Figure 4, one can see an increase in the amount of tyres disposal from 2001 to 2019. However, in 2020, there was a decrease of 19% in comparison to 2019; this was probably due to the COVID-19 pandemic.

Figure 3 – Waste tyres collection points



Source: Based on IBAMA, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018b, 2019, 2020; RECICLANIP, 2020b

Figure 4 – Waste tyres disposal from 2011 to 2020



Source: Based on IBAMA, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018b, 2019, 2020; RECICLANIP, 2020b

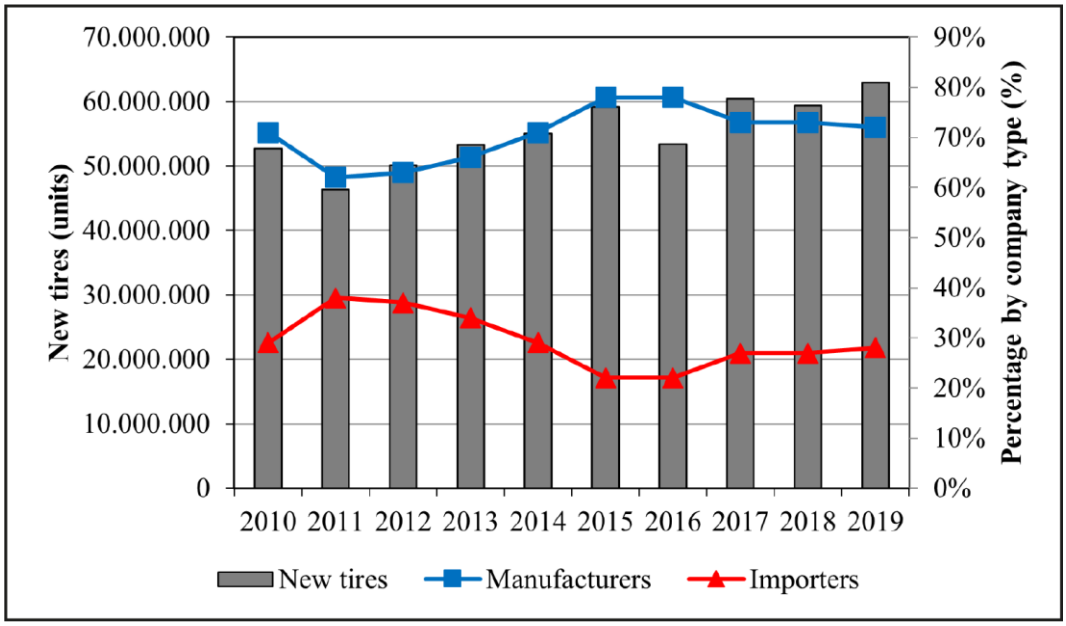
It is essential to highlight that CONAMA Resolution No. 452, of July 2, 2012, prohibited the importation of used tyres (Classification as Inert Waste – Class IIB) (CONAMA, 2012). This prohibition is considered necessary and important to avoid that waste tyres produced in other countries contribute to the increase of this type of waste in Brazil.

3.2 Evaluation of the goal

In order to assess the goal of tyre manufacturers and importer companies, IBAMA's annual reports of 2010 to 2019 were analysed. The replacement market was evaluated first.

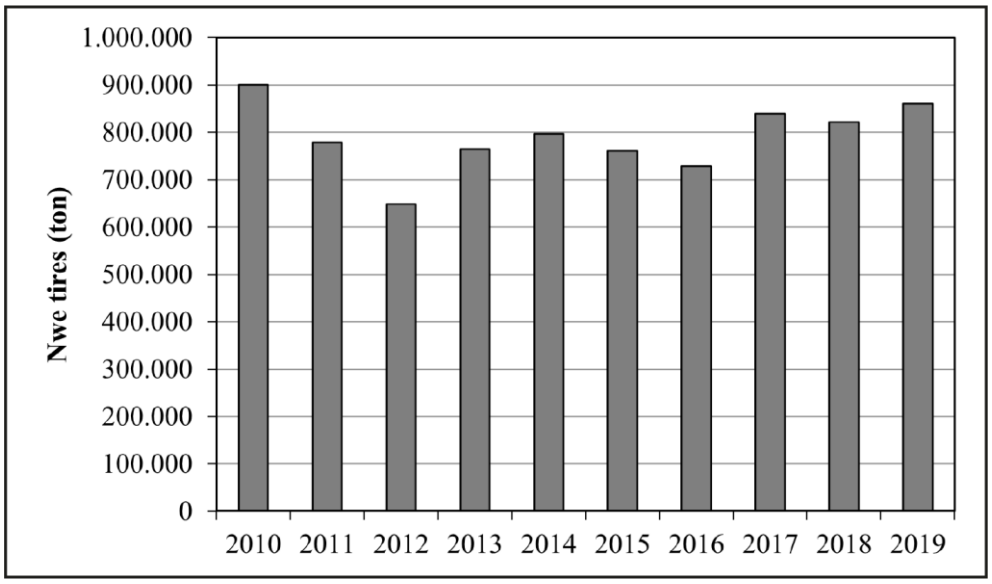
Figure 5 presents the total quantity of new tyres available in the replacement market over 2010−2019, calculated according to Equation 3, and the percentage of participation by sector, produced or imported. Figure 6 shows the quantitative of new tyres produced over the same period.

Figure 5 – New tyres into the replacement market in units and percentage by the supplier



Source: Based on IBAMA, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018b, 2019, 2020

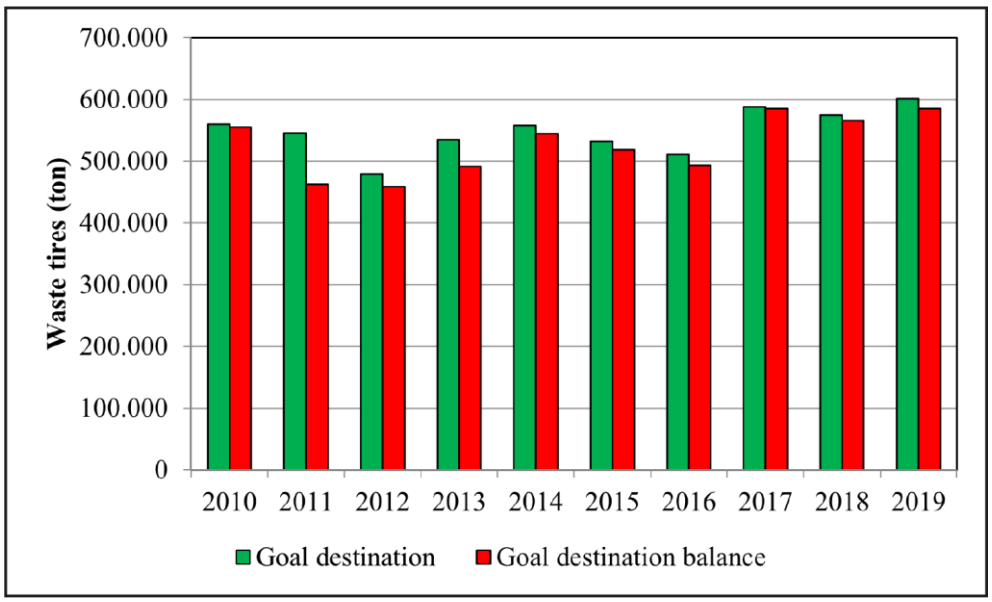
Figure 6 – New tyres into the replacement market in tonnes



Source: Based on IBAMA, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018b, 2019, 2020

The national destination goal for each year, which corresponds to the sum of the individual goals for manufacturers and importers of new tyres and the adequate amount of tyres disposed to meet the goal, represented by the destination balance, is shown in Figure 7.

Figure 7 – National destination goal

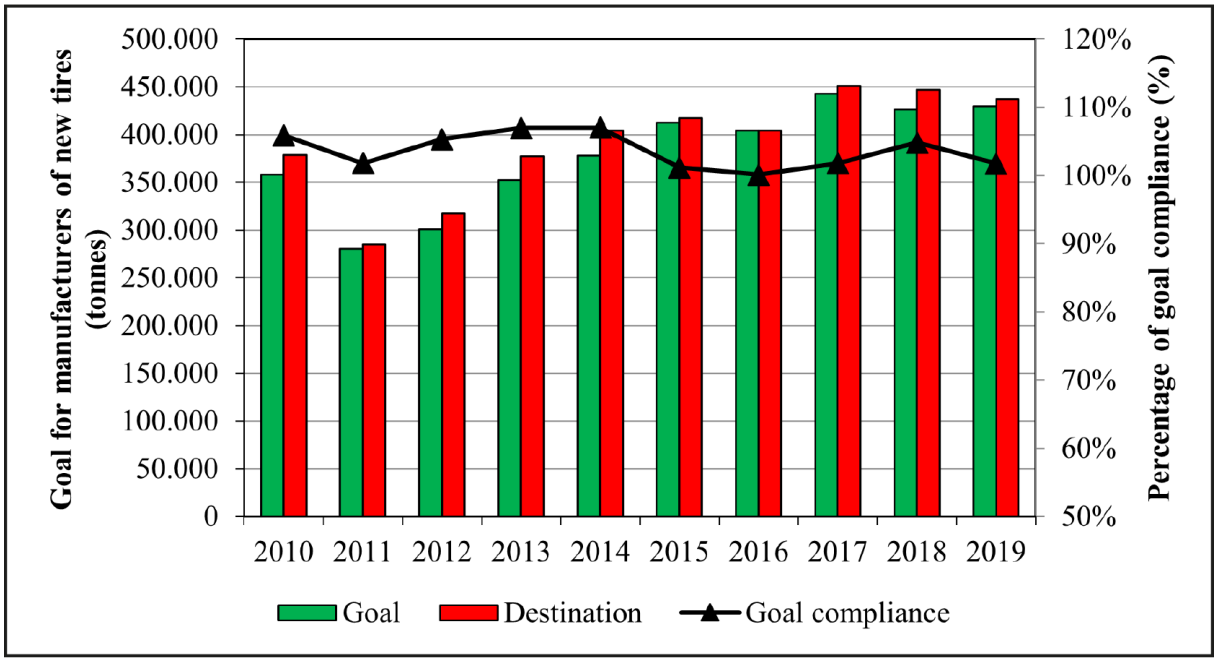


Source: Based on IBAMA, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018b, 2019, 2020

The values in Figure 7 were calculated using Equations 1 and 2. Between 2010 and 2019, 17 manufacturing companies and 531 importing companies declared the data in the Federal Technical Registry. Through Figure 7, it is observed that the total national destination goal was not reached (together for manufacturer and importers).

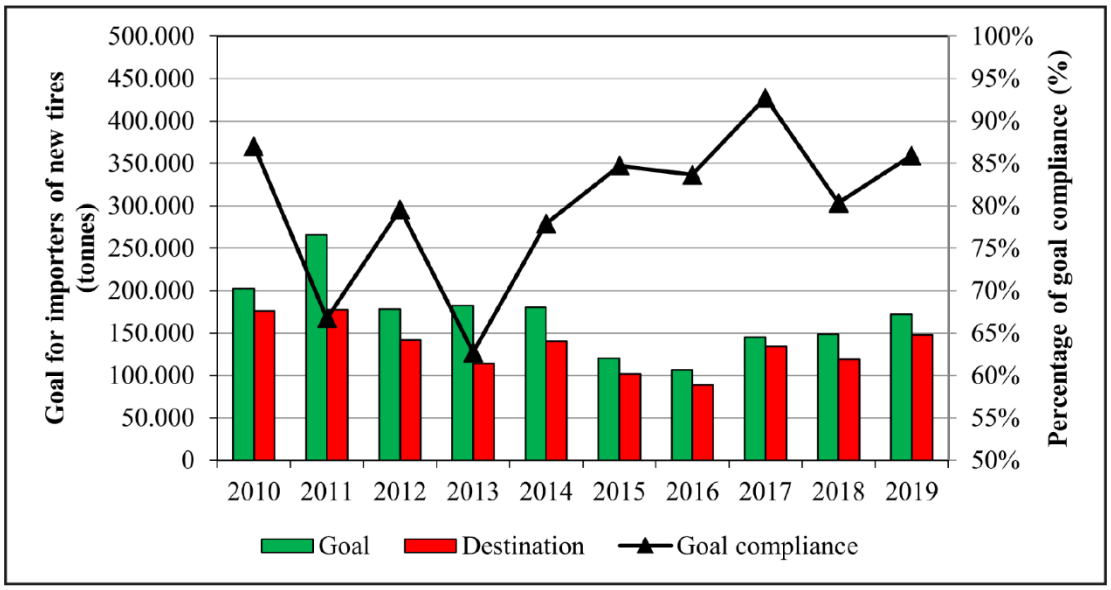
In 2019, the allocation percentage was 97.2% and 2.8% without allocation. However, it is necessary to assess the destination target by manufacturers and importers separately. Figure 8 shows the achievement of the goal, the destination, and the percentage of goal achievement for the manufacturing companies; and Figure 9, for tyre importers. In this year, new tyre manufacturers reached 101.72% of the destination established for 2019, while importers met the goal of 85.92%.

Figure 8 – Goal, destination and percentage of goal compliance by manufacturers of new tyres



Source: Based on IBAMA, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018b, 2019, 2020

Figure 9 – Goal, destination and percentage of goal compliance by of new tyres



Source: Based on IBAMA, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018b, 2019, 2020

3.3 Destinations

Before the awareness of environmental issues, disposal in landfills or stockpiling was the option to manage waste tyres. Waste tyres are an environmental problem and occupy a large volume of landfills, there is a risk of ignition, and the impermeability of landfills is not always guaranteed. In addition to the economic potential that a waste tyre represents, recycling and reusing were established through several processes and activities.

Reverse logistics is an instrument of economic and social development characterized by a set of actions, procedures. It is designed to enable the collection and return of solid waste to the chain production, for reuse, in its cycle or other production cycles, or another appropriate disposal (MMA, 2018). Adequate environmental disposal is considered a technical procedure in which the tyre's constituent elements are reused, recycled, or processed using techniques accepted by environmental agencies (CONAMA, 2009).

The National Solid Waste Policy encourages the practice of reverse logistics and should effectively include the circular economy. The circular economy is a

strategic concept based on reducing, reusing, recovering, and recycling materials and energy. The basis of the circular economy is related to the reuse of the product by the final consumer; in reuse, reassembly, and recycling (SGS, 2021). Gonçalves *et al*. (2019) add that, despite not being widespread in the country, the circular economy incorporates different practices, suitable for small to large companies and generating direct impacts on the economic and productive system. However, the implementation and management practices of the circular economy in Brazil depend on the involvement of the government, institutions, and companies.

Oliveira *et al*. (2019) state that production models aimed at sustainability ideals are necessary and adequate planning of products and processes, extending the useful life of what is produced with the introduction of practices aimed at the reprocessing by-products and reintegration into the production chain.

Reverse logistics, a set of means that collect and return solid waste to the business sector, is linked to the steps of remanufacturing and recycling in the circular economy. These concepts are directly related to the responsibility that everyone has for the life cycle of a product so that it is reused in its production cycle (SOUZA *et al*., 2016; GONÇALVES *et al*., 2019; SGS, 2021).

The most waste tyres disposal activities declared by the disposal companies to the Federal Technical Registry (FTR) in Brazil were as follows (the quantities are presents in Table 3):

- Co-processing: carried out by cement manufacturing companies in which waste tyres are used in clinker kilns as a fuel;
- Lamination: used by companies that manufacture rubber artefacts;
- Recycling: applied by companies that manufacture ground rubber and use steel;
- Rubber regeneration: process carried out by companies that devulcanise rubber;

- Shale industrialisation: applied in companies that co-process oil shale using tyres;
- Pyrolysis: consists of the thermal decomposition process of rubber conducted in the absence of oxygen or in conditions where the oxygen concentration is low enough not to cause combustion; there is generation of oils, steel and carbon black;
- Granulation: industrial process for manufacturing ground rubber, in different granulometries, with separation and use of steel.

Table 3 – Waste tyres types and destination quantity

Year	Destination quantity (tons)						
	Co-processing	**Shale industrialisation**	**Lamination**	**Recycling**	**Rubber regeneration**	**Pyrolysis**	**Granulation**
2010	294,956.94	7,549.51	91,714.70	160,768.18	118.28	-	-
2011	256,481.24	8,334.18	59,197.88	138,313.28	130.62	-	-
2012	219,269.09	9,810.00	61,115.93	-	-	336.03	168,499.14
2013	267,448.35	14,700.00	43,839.44	-	17.47	72.94	165,574.82
2014	300,510.70	-	54,168.63	-	316.28	-	189,699.79
2015	307,015.71	-	82,807.09	-	262.10	6,599.49	122,239.97
2016	297,168.80	-	56,945.41	-	-	5,344.49	133,940.43
2017	274,815.07	-	81,625.74	-	-	13,208.46	215,604.04
2010	326,401.99	-	95,596.99	-	-	9,305.31	135,019.54
2019	366,188.58	-	12,535.83		-	95,788.35	110,878.32
Total	**2,615,299.58**	**40,393.69**	**485,624.62**	**299,081.46**	**844.75**	**130,655.07**	**1,241,456.05**

Source: Based on IBAMA, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018b, 2019, 2020

The burning of waste tyres at high-temperature furnaces is a chemical process to obtain energy. Due to the high calorific value, the residues are used as an alternative fuel in cement kilns, replacing petroleum coke (RECICLANIP, 2020c). The use of waste tyres as a fuel is an economical alternative to fossil fuels,

especially for cement manufacturers, whose energy consumption is one of their most significant expenses. Furthermore, its use reduces nitrogen oxides (NO_x) emissions because incineration is more efficient in relation to other fuels (TURER, 2012; GRAMMELIS *et al*., 2021). According to Table 3, co-processing is the most used activity in the country, i.e. 2,615,299 tons of waste tyres were used from 2010 to 2019.

It is noted that a large amount of waste tyres is collected and sent to recycling or reuse operations that comply with waste disposal regulations. However, not all destinations can be considered environmentally appropriate. Ineffective regulations support the intense demand for fuel for industrial ovens.

Without proper emission control, burning waste tyres indiscriminately can release various toxic chemicals and gases into the environment, but it is economically viable for companies. It is necessary to restrict the burning of tyres in furnaces, inspect the type and amount of emissions, and control employees' health since they are exposed to fine particles resulting from burning and oil and air pollution. Burning of waste tyres activity cannot be considered environmentally appropriate.

When cut and ground, the waste tyres are transformed into rubber powder that passes through a sieving system until the desired granulometry for the intended activity. According to CEMPRE (2020), after particle size reduction, the material undergoes chemical treatment to enable the devulcanisation of the rubber, called the regeneration process. In rotary autoclaves, the material receives oxygen, heat, and intense pressure, which breaks its molecular chain. They can also be mixed with other chemicals to form new end products. The regeneration technique is not significantly used in Brazil; it was more adopted until 2016 (Table 3).

Through a mechanical process of granulation, sieves, and aspiration of fabric fibers, at a low cost and with less environmental impact than chemicals, the material is reused for making car mats, hoses, shoe soles, sports courts, and

industrial floors. This process encompasses recycling, lamination, and granulation activities (CEMPRE, 2020). It is observed that from 2013 onwards, there was an increase in granulation (Table 3), which can be attributed to the development and expansion of the use of asphalt rubber in the production of asphalt mixtures used as flexible pavements surface in Brazil. In the lamination process, non-radial tyres are cut into sheets used to manufacture straps (furniture industry), shoe soles, and rainwater pipes (RECICLANIP, 2020c).

The advantages of granulation are its high economic value, and the process is simple. However, it has limited use of the final product (rubber powder), and the demand depends on the region.

More than 40,000 tons of waste tyres were used in the industrialization of shale between 2011 and 2014 (Table 3). Petrobras, the Brazilian oil company, developed this technology. Crushed tyres are incorporated into the shale load in a volume of up to 5% of the total load (CARVALHO, 2009).

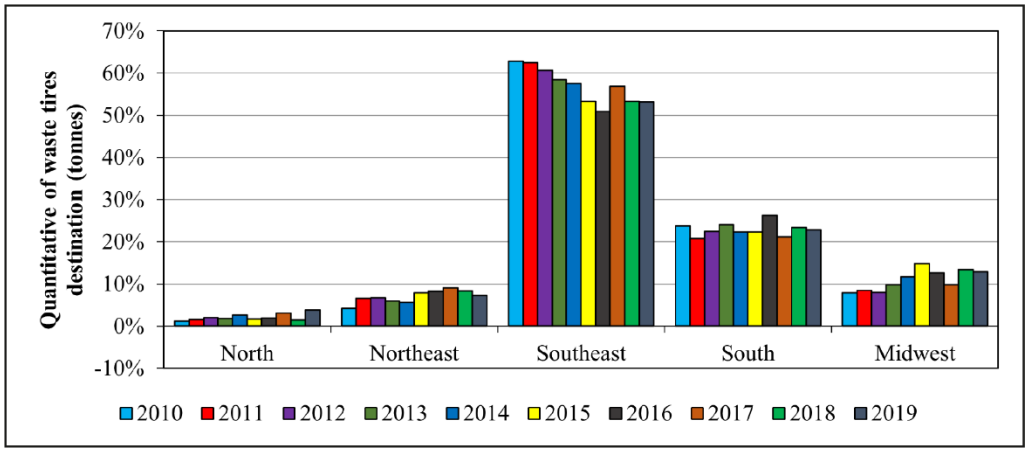
The pyrolysis process of thermal decomposition of rubber is conducted without oxygen or in conditions where the oxygen concentration is low enough not to cause combustion. The process takes place under pressure at temperatures above 430°C and transforms the material into gaseous, liquid, and solid fractions that can be fully reused, including in the tyre production chain. Recycling through tyre pyrolysis is growing in Brazil (Table 3). There is a generation of oils, steel and carbon black (IBAMA, 2020). Xu *et al*. (2019) consider that the pyrolysis process, although applying to all tyres and having high economic value, presents pollution control problems due to the sulfur present in waste tyres. Furthermore, the unqualified pyrolysis plant that does not meet the environmental emission standards will result in air and soil pollution, harmful to the operators.

The United States Environmental Protection Agency (EPA) confirms new uses for waste tyres such as sound barriers on highways and sleepers on railroads. Sound barriers are produced by a mixture of aggregate, cement, water and small pieces of crushed rubber from waste tyres. Rubber railroad sleepers are highly

durable and have a concrete-filled steel beam core encased in shredded tyres; they are 200% more resistant than wooden ones and at least 60 to 90 years more durable than 5 to 30 years of wooden ones (EPA, 2020).

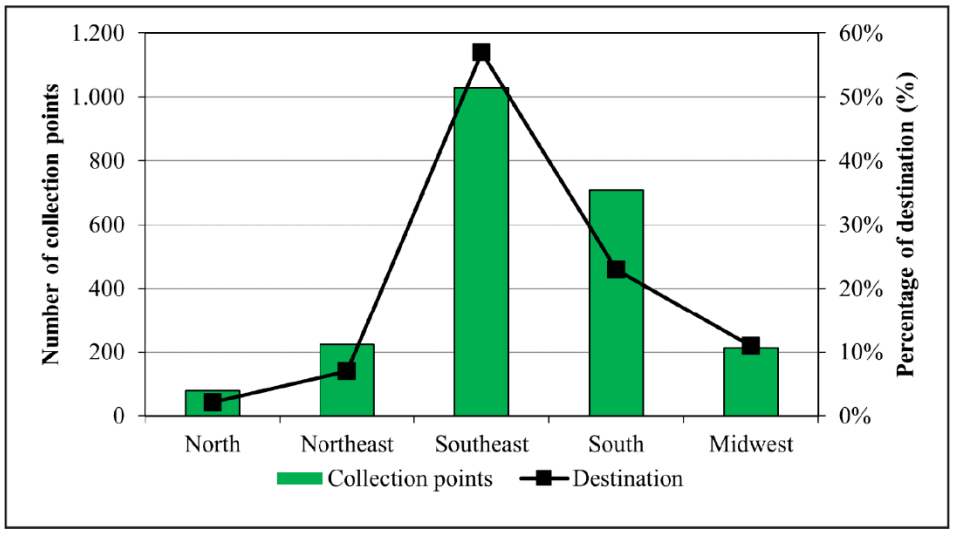
Figure 10 shows the percentage of waste tyres destination for each region. The southeast and south regions present the most significant amount of tyres disposal._The evaluation of the collection points and percentages for the regions, in Figure 11, shows that the southeast and south regions also have more collection points, i.e., 57% and 23%, respectively.

Figure 10 – Percentage of waste tyres destination for each region



Source: Based on IBAMA, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018b, 2019, 2020

Figure 11 – Collection points and e percentage of waste tyres destination for each region



Source: Based on IBAMA, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018b, 2019, 2020

4 CONCLUSIONS

Through CONAMA Resolutions No. 416/2009 and No. 452, and IBAMA Normative Instruction No. 11, Brazil shows that it is one step ahead of many developing countries regarding the disposal and reuse of waste tyres. The National Solid Waste Policy also provides guidelines and corroborates sustainability application in the country. However, the management of waste tyres remains a challenge for Brazilian environmental authorities.

Over the period considered, from 2010 to 2019, the established goals were met by new tyre manufacturers but not by importers. In 2019, manufacturers reached 101.72% of the settled destination, while importers met only 85.92%. In this sense, it is important to establish public incentive policies and, on the other hand, apply pertinent and punitive legislation regarding non-compliance.

As for the waste tyres disposal, it was observed that the southeast and south regions presented the highest quantity of tyres disposed of in relation to the other regions. Such regions also have a higher number of collection points. Thus, a greater incentive should be given to the north, northeast and midwest regions to dispose of a higher amount of waste tyres.

The main waste tyre destination activities in Brazil are co-processing (2,615,299 t), granulation (1,241,456 t) and lamination (495,624 t). It is suggested that new forms of reuse and recycling beyond those already adopted be implemented and that there should be greater adherence to reverse logistics in the country.

Brazil has a reuse of waste tyres policy; however, it is important to note that the data analysed herein refer to the information collected, which may not represent the total number of companies in the country.

REFERENCES

ANIP - Associação Nacional das Indústrias de Pneumáticos, Vendas totais e principais canais de venda, 2020.– Available from: https://www.anip.org.br/sitenovo/wp-content/uploads/2020/04/Vendas-totais.pdf.

BRASIL - Presidência da República, Política Nacional de Resíduos Sólidos. Lei Nº 12.305, de 2 de agosto de 2010 (2010). Brasília, DF, Brasil, Available from: http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm.

CARVALHO, P. Petrobras usa pneu velho para processar xisto, 2009. Available from: https://www.terra.com.br/noticias/ciencia/sustentabilidade/petrobras-usa-pneu-velho-para-processar-xisto,4a38a4b635aab310VgnCLD200000bbcceb0aRCRD.html.

CEMPRE - Compromisso Empresarial para Reciclagem. Pneus, 2020. Available from: https://cempre.org.br/pneus/.

CONAMA - Conselho Nacional do Meio Ambiente. Resolução Nº 416, de 30 de setembro de 2009 (2009). Publicada no Diário Oficial da União (DOU) Nº 188, de 01/10/2009, 64-65.

CONAMA - Conselho Nacional do Meio Ambiente. Resolução Nº, de 02 de julho de 2012. (2012). Publicada no Diário Oficial da União (DOU) em 04/07/2012.

EPA - United States Environmental Protection Agency. Innovative uses for scrap tyres, 2020. Available from: https://archive.epa.gov/epawaste/conserve/materials/tyres/web/html/science.html.

GLOBALSTEIN - Global Tyre Recycling Industry. Analysis by rubber type, by product type, by end user and by geography & covid-19 impact with market Outlook 2017-2030. Industry Research Outlook, 2121 Edition, 2021. Available from: https://www.goldsteinresearch.com/report/global-tyre-recycling-industry-market-trends-analysis.

GONÇALVES, T.M.; BARROSO, A.F.F. A economia circular como alternativa à economia linear. XI Simpósio de Engenharia de Produção de Sergipe, 18 a 22 de novembro, 2019, Sergipe, Brasil.

GRAMMELIS, P.; MARGARITIS, N.; DALLAS, P.; RAKOPOULOS, D.; MAVRIAS, G. A review on management of end of life tyres (ELTs) and alternative uses of textile fibers. Energies. 2021; 14: 571, 1-20. https://doi.org/10.3390/en14030571.

IBAMA - Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. Instrução Normativa Nº 1, de 18 de março de 2010(2010). Ministério do Meio Publicada no Diário Oficial da União (DOU) de 19 de março de 2010.

IBAMA - Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. Relatório de Pneumáticos. Ano base: Out/2009 – Dez/2010, Versão , 2011. Available from: http://www.ibama.gov.br/residuos/pneus#relatorio-pneumaticos.

IBAMA- Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. Relatório de Pneumáticos, Ano base: 2011, 2012. Available from: http://www.ibama.gov.br/residuos/pneus#relatorio-pneumaticos.

IBAMA - Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. Relatório de Pneumáticos, Ano base: 2012, 2013. Available from: http://www.ibama.gov.br/residuos/pneus#relatorio-pneumaticos.

IBAMA - Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. Relatório de Pneumáticos, Ano base: 2013, 2014. Available from: http://www.ibama.gov.br/residuos/pneus#relatorio-pneumaticos.

IBAMA - Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. Relatório de Pneumáticos, Ano base: 2014, 2015. Available from: http://www.ibama.gov.br/residuos/pneus#relatorio-pneumaticos.

IBAMA - Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. Relatório de Pneumáticos, Ano base: 2015, 2016. Available from: http://www.ibama.gov.br/residuos/pneus#relatorio-pneumaticos.

IBAMA - Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. Relatório de Pneumáticos, Ano base: 2016, 2017. Available from: http://www.ibama.gov.br/residuos/pneus#relatorio-pneumaticos.

IBAMA - Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. Instrução Normativa nº 6, de 15 de março de 2013. Regulamenta o Cadastro Técnico Federal de Atividades Potencialmente Poluidoras e Utilizadoras de Recursos Ambientais - CTF/APP. Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA). Publicada no Diário Oficial da União (DOU) de 17 de abril de 2018, 2018a.

IBAMA- Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. Relatório de Pneumáticos, Ano base: 2017, 2018b. Available from: http://www.ibama.gov.br/residuos/pneus#relatorio-pneumaticos.

IBAMA - Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. Relatório de Pneumáticos, Ano base: 2018, 2019. Available from: http://www.ibama.gov.br/residuos/pneus#relatorio-pneumaticos.

IBAMA - Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. Relatório de Pneumáticos, Ano base: 2019, 2020. Available from: http://www.ibama.gov.br/residuos/pneus#relatorio-pneumaticos.

KORDOGHLI, S.; PARASCHIV, M.; KUNCSER, R.; TAZEROUT, M.; PRISECARU, M.; ZAGROUBA, F.; *et al*. Managing the environmental hazards of waste tyres. Journal of Engineering Studies and Research. 2014; 20(4): 1-11.

MMA – Ministério do Meio Ambiente. Pneus inservíveis. Nacional de Informações sobre a Gestão dos Resíduos Sólidos – SINIR, 2018. Available from:

https://sinir.gov.br/index.php/component/content/article/2-uncategorised/123-pneus-inserviveis.

OLIVEIRA, F.R.; FRANÇA, S.L.B.; RANGEL, L.A.D. Principles of circular economy for the development of products in industrial clusters. Interações. 2019; 20 (4): 1179-1193.

RECICLANIP. Ciclo do pneu, 2020a.. Available from: https://www.reciclanip.org.br/formas-de-destinacao/ciclo-do-pneu/.

RECICLANIP. Destinados, 2020b.. Available from: https://www.reciclanip.org.br/destinados/.

RECICLANIP. Destinados, 2020c. Available from: https://www.reciclanip.org.br/formas-de-destinacao/principais-destinacoes/.

SGS Sustentabilidade. Os benefícios da economia circular e logística reversa, 2021. Available from: https://sgssustentabilidade.com.br/beneficios-da-economia-circular-e-logistica-reversa/.

SOUZA, N.; SOUZA, B.B.; VIEIRA, R.C. O papel da logística reversa na economia circular entre empresas de diferentes setores: um estudo de caso. Encontro Nacional sobre Gestão Empresarial e Meio Ambiente, 2016. ISSN: 2359-1048.

TURER, A. Recycling of scrap tyres. Material Recycling – Trends and Perspectives, chapter 8, 2012. doi: 10.5772/32747. Available from: https://www.intechopen.com/books/material-recycling-trends-and-perspectives/use-of-scrap-tyres-in-industry.

XU, S.; LAI, D.; ZENG, X.; ZHANG, L.; CHENG, J.; WU, R.; *et al*. Pyrolysis characteristics of waste tyre particles in fixed-bed reactor with internals. Carbon Resources Conversion. 2018; 1: 228–237.

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