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WASTE TYRE REVERSE LOGISTICS IN NORTHERN BRAZIL

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ABSTRACT

Considering the growing concern about environmental protection and the large-scaletyre manufacturing industry, the problem of improperly disposing of tyre waste has called attention. This paper aims to identify the waste tyre reverse logistics scenarioin Northern Brazil based on tyre reports drawn up by the Brazilian Institute of Environment and Natural Resources (IBAMA). The methodological procedure of this study consists of documentary research, where the IBAMA tyre reports from 2011 to 2017 were analysed to obtain data, using the descriptive analysis technique. The study identified a waste tyre disposal scenario in the Northern Region, and it was found that in 2014 there was a very high disposal when compared to the other years analysed. The Northern Region accounted for only 13% of the national disposal in 7 years of analysed reports and showed a different scenario from the other regions in Brazil. The research concluded that the Northern Region needs investment and collaboration from the private sector, consumers and the public sector to further develop and improve waste tyre reverse logistics in the study area.

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INTRODUCTION

Taking into accountthe increasing concern about environmental protection and thelarge-scale tyre manufacturing industry, the issue of improper tyre waste disposal has increased mainly due to its challenging degradability characteristics and to the fact that it takes upample space in landfills (DHOUIB, 2014). There are estimates that indicate there are over 4.8 billion tyres in use worldwide, in which approximately 4 billion waste tyres are generated each year (SENGUL, 2016). In Brazil, according to the National Tyre Industry Association (ANIP, 2016), in 2016, more than 67 million tyres were produced and 60 million sold

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in the same year. It is estimated that 450 thousand tons of tyres are discarded annually in the country (SEST, 2017) and when this activity occurs improperly, it can cause damage to public health and the environment (SOUZA; D'AGOSTO, 2013a). Damage caused to the environment by products that were incorrectly discarded has caused society to demand ways of controlling, reducing and reversing impacts from the competent agencies. Considering this, environmental laws and regulations were adopted aimed at properly disposing of used products (IBÁÑEZ-FÓRES *et al.*, 2018). Among the legislations, the promulgation by the National Environment Council - CONAMA, of Resolution No. 416, 30th September, 2009 (CONAMA, 2009) can be highlighted, which prevents environmental degradation caused by waste tyres and suitable environmental disposal. In addition, the National Policy on Solid Waste (PNRS in Portuguese), established by Law No. 12,305 of 2ndAugust, 2010 (BRASIL, 2010), is also an important initiative to mitigate environmental damage caused by tyres.The PNRS establishes that tyre manufacturers, dealers and importers should develop an End-of-Life Reverse Logistics system and regulate that waste management responsibility is shared by all those involved: companies, society and governments (BRASIL, 2010). According to the Brazilian Institute of Environment and Renewable Resources (IBAMA), in 2016, 493,000 tons of waste tyres were correctly disposed of in Brazil. In contrast, the Northern Region of the country accounted for only 9 thousand tons, representing 1.94% of the disposal (IBAMA, 2017) despite having a fleet of about 2 million vehicles (DENATRAN, 2018). This low contribution from the region associated with the high number of vehicles can make the problem of irregular disposal of waste tyres worse (MACHIN; PEDROSO; CARVALHO, 2017). Thus, this article aims to identify the waste tyrereverse logistics scenario in Northern Brazil based on tyrereports drawn up by IBAMA and propose management strategies for the system studied.

MATERIALS AND METHODS

The problem of tyre waste: According to Czajczyńska *et al* (2017), approximately 1.5 billion tyres are produced every year around the world, which corresponds to 17 million tons of used tyres.This addresses a particular environmental problem when this high amount of tyres reaches the end of service life and becomes waste. In Brazil, the Brazilian Association of Technical Standards (ABNT in Portuguese), through NBR 10004/2004, classifies waste tyres as inert waste, which must be disposed of in landfills (ABNT, 2004). However, research on tyre waste has established that because of its physical and chemical characteristics, it can no longer be disposed of in landfills (HAN *et al*, 2018). These characteristics include: tyre dimensions; low compressibility; the fact that they are not biodegradable; and when they come into contact with the gases generated in the landfill can swell and burst, thus making them unfit for landfill (LUZ; DURANTE, 2013; CHEN *et al*, 2018).When placed in open spaces, the tyres serve as mosquito breeding grounds due to their opaque shape that accumulates water and generates a suitable microclimate for the proliferation of this vector, making public health control measures difficult to implement (DINH; NOVAK, 2018). Incineration of this waste improperly releases toxic and carcinogenic gases, as well as oils, which can percolate and contaminate the soil and groundwater in the area where there is irregular burning (RAMARAD *et al*, 2015). Therefore, incineration as an option for disposing of this waste should be avoided due to the severe impacts on the environment and human health (ZAITER *et al*, 2018).Tyre waste disposal in inappropriate places, such as rivers and streams in general, causes obstruction of water passages, as well as siltation of water resources, increasing the risk of flooding in cities, and promoting loss of water quality (LUZ; DURANTE, 2013).Thus, the proper disposal of waste tyres is fundamental to solve countless environmental problems linked to this environmental liability, and facilitates recycling and reuse processes, which bring economic, social and environmental benefits (SONG *et al*, 2018; ISLAM *et al*, 2018).

National Policy on Solid Waste (PNRS): Authorised on 2ndAugust, 2010, Law No. 12.305 established the National Policy on Solid Waste (PNRS in Portuguese), which addresses a set of principles, objectives, instruments and guidelines related to integrated management and environmentally sound management of solid waste adopted by the Federal Government, alone or in cooperation with States, the Federal District, Municipalities or individuals (BRASIL, 2010). Among the main points addressed in the PNRS, the concept of shared responsibility should be mentioned, which recognises the participation of the private sector, consumers and other governmental spheres in solid waste management (DICKEL *et al*, 2018; BRAZIL, 2010). The law also establishes drawing up solid waste management plans for public authorities with situational diagnosis and recycling, reuse and reduction measures of the amount generated of these residues (MARINO; CHAVES; SANTOS, 2018). As one of the main objectives, PNRS sought to stop using dumps, replacing them with landfills and implementing selective collection, reverse logistics and organic material composts (BRASIL, 2010; FERRI; CHAVES; RIBEIRO, 2015). Thus, the Law also recognises reusable and recyclable solid waste as an economic good and of social value, considering actions that involve shared responsibility for product life cycles (BRASIL, 2010). The PNRS considers reverse logistics as a central instrument for implementing shared responsibility that can lead to a set of actions for collecting and returning products and solid waste remaining for the business sector, to reuse in its cycle or in other production cycles, or even another environmentally friendly form of end disposal (ABRELPE, 2016; GUARNIERI; STREIT, 2015). Endowed with this instrument, Law No. 12.305/10, article No. 33 determines the obligation of tyre manufacturers, importers, distributors and traders to implement a reverse logistics system, upon return products after use by the consumer, irrespective of the public urban cleaning service and solid waste management.

Reverse Logistics: Competitive pressures and technological advancement have led to a reduction in the life cycle of products and development of new materials, thus expanding reuse and recycling activities, benefitting the inclusion of reverse logistics in management processes (DEMAJOROVIC; AUGUSTO; SOUZA, 2016).Furthermore, the focus on legislation with environmental protection and consumer environmental awareness has placed reverse logistics in the spotlight and, has thus received more attention from researchers and supply chain managers (SANGWAN, 2017). Considering this, companies are investing more in adopting reverse logistics strategies due to the economic benefits and improvement of the social corporate image, thus increasing the importance attributed by the market to reverse logistics activities (AGRAWAL; SINGH; MURTAZA, 2015). Reverse logistics is taken as the process of planning, implementing and controlling reverse flows of raw materials in process inventory, packaging and finished products, from manufacturing, distribution or use, to recovery or proper disposal (ROGERS; TIBBEN-LEMBKE, 1998). Genchev (2009) defines reverse logistics as the the process of moving and storing goods from their typical final destination for the purpose of recapturing value, or properly disposing of them appropriately in ecologically appropriate places. The Reverse Logistics Executive Council (RLEC), the world's leading body on the subject, defines reverse logistics as the process of moving goods from their typical destination to another point for the purpose of obtaining value otherwise unavailable, or with the purpose of final product disposal (RLEC, 2018). According to the PNRS (BRAZIL, 2010), reverse logistics is considered as an instrument of economic and social development, characterized by a set of actions, procedures and means designed to enable the collection and return of solid waste to the business sector to reuse it in its cycle or in other production cycles, or another environmentally appropriate final destination. Therefore, reverse logistics is generally characterized as a set of planning, control and decision-making activities focused on the flow of goods, waste, materials or parts, from consumer to producer, with the purpose of revaluing, extending life cycles. and reducing waste, or disposing of it correctly, and thereby contributing to sustainable development (FONSECA *et al*, 2017; OLIVEIRA; MARINS; JÚNIOR, 2016). Reverse logistics is precisely the strategy that fulfills the role of operationalising the return of after-sales and post-consumer waste to the business and/or productive environment, considering that only disposing of waste in controlled landfills, or dumps is not sufficient in the current business context (AGRAWAL; SINGH; MURTAZA, 2015).

Tyre manufacturing began in Brazil in 1936 and tyre collection operations began in 1999, when in this year alone 2.68 million waste tyres were collected and recycled (POLZER; PISANI; PERSSON, 2016; FAGUNDES; AMORIM; LIMA, 2017).To consolidate this tyre waste collection system, Reciclanip was created in 2007 by tyre producers, which is considered one of the largest investments of the national industry in the field of reverse logistics (POLZER; PISANI; PERSSON, 2016). Before promoting Brazilian legislation (CONAMA, 1999; CONAMA, 2009; IBAMA, 2010; BRAZIL, 2010) for the proper collection and disposal of waste tyres, only 10% of the tyres were recycled (LAGARINHOS; TENÓRIO, 2013). These legislations have made tyre manufacturers responsible for implementing reverse logistics channels for this waste and sectoral agreements have been set up with the government in order to consolidate the logic of shared responsibility for the life cycle of tyres (MAGALHÃES; RIBEIRO, 2017).Thus, the number of registered companies and jobs created to operate in the reverse logistics system through transportation, reuse, recycling and energy recovery of tyres has increased, driving the economy of this sector (IBAMA, 2017; LAGARINHOS; TENÓRIO, 2013; GODLEWSKA, 2017). The reverse logistics system managed by Reciclanip, having agreements with City Halls, has a total of 1024 collection points, installed all over Brazil (RECICLANIP, 2018). These points must be installed in municipalities with a population of over 100 thousand inhabitants, and may include, in addition to the municipal governments, places to sell tyres and repair shops in the reverse logistics system (CONAMA, 2009). In Brazil, the main means of properly disposing of waste tyres is as an alternative fuel for the cement industry, which in 2017 accounted for 60.23% of the total. Second in the classification is the manufacturing of rubber granules and powder to use in rubber artifacts, or asphalt rubber, accounting for 27.15% of the disposal. Following that is the rolling mill, which uses waste tyres as a raw material to manufacture shoe soles, river ducts, etc., which account for 11.54%, and finally using it in the pyrolysis process with 1.08% (IBAMA, 2017).Thus, due to the success of Reciclanip's actions and the emergence of the PNRS in 2010, more recent attention has been given to the issue of waste tyres by the main Brazilian cities and capitals, establishing partnerships and concrete measures to make the collection and environmentally appropriate disposal of this environmental liability in the country (FLORIANI; FURLANETTO; SEHNEM, 2016).

METHODOLOGY

Applied research was adopted, because it sought to generate knowledge for applications aimed at the problem of waste tyres. Concerningthe objectives, it is characterized as exploratory research, as it provided more information about the reverse logistics of waste tyres in the Northern Region of Brazil (PRODANOV; FREITAS; 2013).The methodological procedure adopted in this study was documentary research, whose data on the reverse logistics of waste tyres were obtained from technical reports prepared by IBAMA. Documentary research addresses materials that can be used as a source of information, which have not yet received analytical treatment, or can be redesigned according to the study objectives (PRODANOV; FREITAS, 2013). The Northern Region corresponds to the states of Acre, Amapá, Amazonas, Pará, Rondônia, Roraima and Tocantins. This region has an estimated 17.92 million inhabitants, representing 8% of the Brazilian population, and has an estimated demographic density of 4.65 inhabitants per km² (IBGE, 2017). The Northern Region has a territorial area of 3,853,327.20 km² (IBGE, 2010) and an estimated vehicle fleet of 2 million, mainly concentrated in the state capitals (DENATRAN, 2018). The northern states have 56 points registered with IBAMA to be able to receive tyre waste and properly dispose of it (IBAMA, 2017). IBAMA is responsible for collecting information from tyre manufacturers by registering and proving the disposal, and thus preparing annual reports on the situation of properly disposed waste tyres in Brazil (IBAMA, 2010; CONAMA, 2009). Reports will be analysed from 2011 to 2017 in order to verify the amount of waste tyres in the Northern Region of Brazil. The data analysis technique used was descriptive analysis and the results were discussed according to legislation that regulates the situation of proper tyre disposal and the relevant literature on waste tyre reverse logistics. Thus, the methodology steps were structured in order to identify the scenario of waste tyre reverse logistics in the Northern Region based on IBAMA reports and to develop management strategies that contribute to the tyre reverse logistics in the study area.

RESULTS

IBAMA tyre reports have been prepared annually since 2011 and aim to comply with the provisions of Art. 16 in the CONAMA Resolution No. 416 of 30thSeptember, 2009, which prevents environmental degradation caused by waste tyres. These documents are fed with consolidated data on the disposal of waste tyres for the year prior to their publication

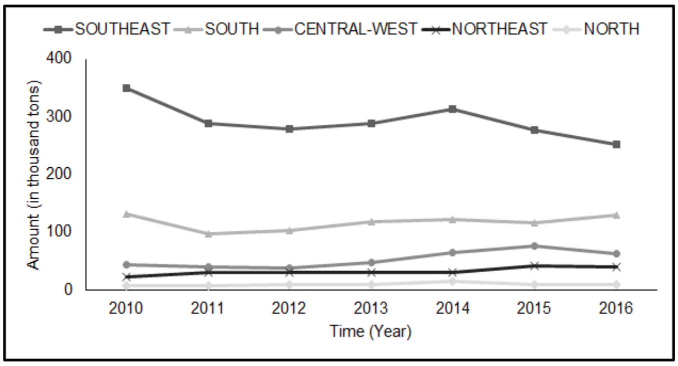
(CONAMA, 2009).Based on this, the disposal profile of the Northern Region in Brazil was configured according to the appropriate tyre volume stated in the IBAMA tyre reports. Table 1 presents the amount allocated by the Northern Region according to the reports from 2011 to 2017. It is worth mentioning that the base year for preparing these documents is always the one prior to their publication.

Table 1. Amount of waste tyres properly disposed of in the North Region of Brazil

Year	Number of tyres disposed(in tons)	% of national disposal
2010	7,001,34	1.26%
2011	7,421,17	1.60%
2012	9,498,65	2.07%
2013	9,032,5	1.84%
2014	14,597,51	2.68%
2015	9,045,9	1.75%
2016	9,552,63	1.94%
TOTAL	66,149,7	13.14%

Source: Data taken from IBAMA reports in August 2018.

Table 1 shows that since the creation of the PNRS, progress has been made in waste tyre reverse logistics collection, in which 2014 can be highlightedas 14 thousand tons of waste tyres were properly disposed. In 2014, when Reciclaniphad been in the waste tyre reverse logistics market for15 years there was a 10.15% increase in the percentage and investment of 99 million reais by tyre manufacturers in the reverse logistics process (RECICLANIP, 2018).In the same year, it can be observed that there was a greater amount of waste tyres in the Northern region to be collected by the program established by Reciclanip. These tyres that have not collectedand disposed of properly can cause environmental and human health problems (CZAJCZYNSK *et al*, 2017). The data presented in the IBAMA tyre reports also showed differences in the number of tyres disposed of in reverse logistics compared to other Brazilian regions, as shown in Figure 1. In addition, from 2011 to 2017, the Northern region participated in only 13% of the total correct disposal of waste tyres, as shown in Table 1.



Source: Adapted by the authors (2018)

Figure 1. Amount of waste tyres disposed of per region in Brazil

This information has enabled us to analyse the waste tyre reverse logistics system established in the Northern region of Brazil, demonstrating a smaller number of tyres properly disposed of in relation to other regions. In contrast, this waste is continuously produced (SOUZA; D'AGOSTO, 2013a) and its generation is constantly rising due to the growth of the regional vehicle fleet (DENATRAN, 2018). In 2016 alone, 96,000 new vehicles were licensed in the states of the Northern Region (CNT, 2017). The fact that roads are used on a large scale throughout Brazil also contributes to the accumulation of waste tyres. It is estimated that 60% of the transportation of people and cargo is done by highways and roads (CNT, 2018). The Northern region has about 21 thousand kilometres of paved roads and 93 thousand kilometres of unpaved roads, making it possible for vehicles to circulate, and thus tyre wear becomes waste (CNT, 2017). The increase in the number of vehicles in the region is directly related to the growth in tyre production and the potential impact of this sectort (SANTOS; BOTINHA; LEAL, 2013). In 2012, the Institute of Applied Economic Research (IPEA in Portuguese) made a diagnosis of solid waste that was established by the PNRS as obligatory to have a reverse logistics system, including tyres. This study shows that 39 municipalities in the Northern Region had a management system for tyres, corresponding to less than 1% of the total number of municipalities in the region (IPEA, 2012). Municipalities' participation in tyre waste management demonstrates that sectoral agreements are being made between the tyre industry sector and the government, as provided for by Law No. 12.305. Responsibility for this waste should be shared by all levels (consumers, the private sector and the government) to minimise environmental damage and the volume generated (BRASIL, 2010). However, the number of municipalities that practice tyre waste management needs to be increased to enhance the reverse logistics system of this sector in the study area. The Brazilian National Confederation of Industry (CNI in Portuguese) studied economic instruments provided by Law No. 12.305/2010 and highlighted the importance of reverse logistics systems as an economic mechanism for creating opportunities for small, medium and large companies to carry out collection, sorting, transportation, recycling and reuse activities (CNI, 2014). Therefore, when developing reverse logistics operations, they encourage job creation and agreements with companies operating in this sector and strengthen waste tyre reverse logistics activities.

Khor *et al* (2016) researched reverse logistics in Malaysia and stated that increased legislation enforcement is the key to making commitments with industries to prevent pollution through the recovery of products such as tyres. The authors further state that reverse logistics management is an emerging practice that meets the goals of sustainable production and consumption. In this perspective, the municipalities from the Northern region should invest in enforcing current legislation regarding tyre waste management and reap the environmental, social and economic benefits related to this practice. According to Eltayeb and Zailani (2011), applying environmental legislation results in the growth of the number of companies that adopt reverse logistics initiatives aiming to comply with the regulatory framework, not being subjected to penalties and fines. Legislation governing the proper collection and disposal of waste tyres seeks to reduce problems caused by this waste, such as fires, river pollution, vector proliferation and non-degradation due to constituent materials (TSAI *et al*, 2017; SVOBODA *et al*, 2018). By concentrating many natural resources, the Northern region needs tyre manufacturers, residents and consumers to comply with legislation and be active in the waste tyre reverse logistics process, sharing responsibility to prevent environmental and human health damage. Rakhmangulov *et al* (2017) analysed various studies in the area of sustainable development and considered that the practice of reverse logistics activities can solve environmental problems implementing sustainable development principles. Thus, improving these activities in the Northern Region can lead to proper waste tyre disposal shown in IBAMA's annual reports and boost the prospects for sustainable development for the study area. The IBAMA Tyre Report (2017) also addresses the number of companies registered in the Northern Region to follow the proper tyre disposal process. There are only 5 companies registered, of which 4 are located in Amazonas and 1 in Pará (IBAMA, 2017).This shows that the other 5 states of the Northern region (Acre, Rondônia, Roraima, Amapá and Tocantins) need to move their waste tyres to other locations, increasing transportation distance and logistics costs. Souza and D'Agosto (2013b) point out that logistics costs account for about two thirds of the total cost of processed tyres and corroborates the importance of conducting studies on the configuration of the reverse logistics network to reduce such expenses. According to information from the IBAMA tyre report, there are only 56 registered points in the Northern Region that receive waste tyres from traders and consumers. Reciclanipcalls these collection points "Ecopoints" and can be found in the legislation regarding proper waste tyre disposal

Bernardo and Lima (2017) studied the planning and implementation of selective collection programs, highlighting that Ecopoints serve as a link between the final consumer and the available treatment options, where the planning of these establishments optimizes the use of resources and human material.

In this context, establishing more Ecopoints and strengthening collection systems in the Northern Region, in conjunction with the reverse logistics actors in this sector, is essential for the preparation of a Waste Tyre Management Plan, as required by CONAMA Resolution No. 416/09. There is also a need to raise awareness among participants in the waste tyre reverse logistics chain through environmental education and access to information for the proper functioning of reverse logistics in the Northern Region as a whole. This can be clearly seen in the study conducted by Floriani, Furlanetto and Sehnem (2016), who when addressing the waste tyre collection and disposal process in Brazil, found that the implementation of waste tyre reverse logistics systems requires consumers, dealers and tyre repair shops to be environmentally aware of the impacts of this waste. The CONAMA Resolution 416/09 and PNRS defend implementing educational programs with the entities involved in the waste tyre reverse logistics process in order to offer guidance to consumers that ranges from collection to final disposal. Disseminating knowledge is important in terms of having a successful and improved waste tyre reverse logistics process in the Northern region of Brazil, thus changing the current disposalpractice found in the national tyre reports issued by IBAMA.

Final considerations

The study identified the waste tyre reverse logistics scenario in the northern region of Brazil based on the tyre reports prepared annually from 2011 to 2017 by IBAMA. It was possible to make a profile of the main points addressed in the reports, especially regarding the amount of waste tyres properly diposed of by the study area. Important aspects found in this scenario were considered to propose management strategies that would contribute to improving activities related to waste tyre reverse logistics in the Northern region. Research on the proper disposal of tyres in this region is relevant in view of the environmental and human health impacts that irregular disposal of this material may cause. In addition, the Northern region lacks information and studies to support public authorities and tyre manufacturers that collaborate with the reverse logistics system implemented. Therefore, investment in the sector is needed, involving all the players in the reverse logistics chain and the scientific community to identify bottlenecks and expand the reverse logistics activities of tyres in the region. Investing in the sector can lead to increasing the efficiency of the process, generating income and employment for those who work in transportation, sorting, collection, disposal and recycling activities. This should be corroborated by enforcing laws regulating the waste tyre reverse logistics, and thus increasingly approximating the concept of sustainable development. Thus, this paper met the proposed objective of identifying the waste tyre reverse logistics scenario in the Northern Region, based on the IBAMA tyre reports and proposing management strategies for the reverse logistics system addressed. Finally, it is suggested that further research should be conducted to gather primary data from the actors involved in waste tyre reverse logistics for the region in order to provide more information to stakeholders interested in managing the waste tyre reverse chain and to avoid the damage caused by this environmental liability.

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