RESEARCH ARTICLE   **OPEN ACCESS**

ANALYSIS OF PUBLICATIONS ON OCCUPATIONAL SAFETY AND HEALTH IN WASTE MANAGEMENT: A SYSTEMATIC REVIEW

Claudenize Pereira Galvão da Silva*, Ana Rosa Bezerra Martins, BédaBarkokébas Júnior, Eliane Maria Gorga Lago and TomiZlatar

Occupational Safety and Hygiene Laboratory, Polytechnic School, Universidade de Pernambuco

ARTICLE INFO

ABSTRACT

Population, urbanization and economic growth have caused waste generation rates to increase exponentially in recent decades. The inadequate disposal of waste as well as the disregard for waste management policies can not only cause damage to society and the environment, but also to workers who deal with different types of waste. The present work aims to identify the main scientific studies that address waste management linked to occupational safety and health and its main characteristics in order to understand which types of waste are most studied. The PRISMA systematic review methodology was applied with two pre-defined keywords: "occupational safety" and "waste management". From the 147 selected articles, it were found four main types of publication, 32 years of publication, 67 journals/books where the studies were published, 19 types of waste, and authors from 26 countries. In the last decade, publications were stronger in both general and the four most common waste categories (E-waste, hazardous waste, medical waste and municipal waste). 2019 was the year with the most publications, and the European Union published most studies, In relation to the type of publication, research articles were the most present format. The most used mean of publication was the Waste Management journal.

INTRODUCTION

In recent decades, population, urbanization and economic growth have caused waste generation rates to increase exponentially. Changes in society's production and consumption patterns have made this generation of waste a concern for human health and for the environmental protection. Over 2.1 billion tons of Solid Urban Waste (MSW) are globally generated each year. However, only 16% of this waste is recycled. Among the G20 countries, China and India together represent more than 36% of the global population and produce around 27% of the world waste. On the other hand, the United States represents only 4% of the world population, but it produces around 773 kg of waste per person per year, which corresponds to 12% of the global MSW (Nichols and Smith, 2019). There are several types of waste. In Brazil, for example, the classification is made in accordance with the National Solid Waste Policy; through Law No. 12,305, from

August 2, 2010, which explains, in its article 13, about classification and definition of types of waste. The waste is classified into two types according to the origin and dangerousness. Concerning to the origin, there are 11 subtypes, they are: household; urban cleaning; urban solids; from commercial establishments and service providers; public basic sanitation services; industrial; health services; civil construction; waste generated from agricultural and forestry activities; transport services; and, finally, mining. Relative to dangerousness, wastes are classified into 02 subtypes: hazardous wastes, those which due to their flammability, corrosivity, reactivity, toxicity, pathogenicity, carcinogenicity, teratogenicity, and mutagenicity characteristics represent a significant risk to public health or environmental quality; and non-hazardous waste, those not classified in the previous classification (BRASIL, 2010). This country, despite having a well-defined waste management policy, still has about 70% of its urban waste disposed-off in open dumps and/or uncontrolled landfills (Nascimento *et al.*, 2019).

Before the 1970s, the management of urban solid waste basically consisted of depositing waste in open dumps and burning it in order to reduce its volume. Usually, hazardous waste from industries was discarded along with solid urban waste, which favored soil and groundwater contamination, emissions of toxic fumes and greenhouse gases, and the spread of disease through rodents and insects (US EPA, 2017a). Currently, in order to minimize these impacts, landfills follow federal, state and/or municipal laws. In agreement with the Brazilian Solid Waste National Policy, solid waste management is the set of actions performed, directly or indirectly, in the stages of collection, transportation, transshipment, treatment and environmentally appropriate final destination of solid waste and environmentally appropriate final disposal of waste, in accordance with a solid waste management plan. Through management, the following order of priority must also be observed: non-generation, reduction, reuse, recycling, solid waste treatment and environmentally appropriate final disposal of waste (BRASIL, 2010).

Inadequate waste disposal as well as disregard for waste management policies can not only cause damage to society, such as contamination of the environment and the proliferation of diseases described in the previous paragraph, but also cause immediate or long-term damage to the workers who handle different types of waste. Workers dealing with MSW, for example, are highly exposed to health risks due to exposure to heavy workloads, bioaerosols, volatile compounds, potentially dangerous or even infectious materials, as well as being subject to musculoskeletal, dermal, respiratory and gastrointestinal problems (Poulsen *et al.*, 1995). In addition, these workers are exposed to accidental risks, with several causes associated with their occurrence. The research by (Diniz *et al.*, 2019) reviewed several studies involving 473 accidents, and found that 45.03% were caused by sharp materials and 25.37% by falls. Together, these two causes represented 70.40% of the total number of accidents registered in the urban solid waste collection service. The additional 30% were caused by excessive effort, operation of the compactors, traffic, lack of attention, absence of collective or individual protection equipment, among others. Once the current scenario of solid waste worldwide is presented, as well as its impact on the environment and public health, including the impact on workers' health, the present work aims to identify the main scientific studies that address waste management linked to occupational health and safety and its main characteristics such as years and types of publication, types of waste considered, studies country of origin, all in order to understand what types of waste are most studied, and what have been arousing the interest of scholars.

METODOLOGY

This article was prepared through a systematic review which followed the PRISMA research method. The studies were searched by using the Science Direct database platform. The search was conducted by title and subject with keywords in English using the following expressions: "occupational safety" AND "waste management". As exclusion criteria, three parameters were used. The first was related to the type of publication, delimiting into four categories: reviews, research articles, book chapters and others. The category "others" consisted of publications such as different documents, articles from encyclopedia, discussions, editorials, mini reviews, practical guides, conference summaries, errata, indexes, and bibliographies. The second criteria was the exclusion of articles which were not associated to occupational exposure to risks involved in waste management. The third criteria was the exclusion of repeated articles. These articles were simultaneously excluded through title and abstract selection. There were no limitations on the year of publication. Finally, additional articles on the topic, known to the authors, were included in the review. After this screening, a spreadsheet was created with information such as title, type and year of publication, summary, name of the journal or book, origin countries, and types of waste studied in the articles. In order to better demonstrate the evolution of the articles production over the decades, the years of publication were subdivided in four groups, which were graphically presented. The first group, with a smaller number of articles published, includes years of publication before 1990, and the other three groups represent the past three decades, respectively, from 1990 to 1999, 2000 to 2009 and 2010 to 2019. In relation to the types of publication, these were also graphically presented in order to identify which books and journals have published most of the included articles during the last decade. Finally, a graphic analysis was carried out involving the number of publications and the types of waste.

RESULTS

The initial search with the "occupational safety" AND "waste management" keywords resulted in 12,233 articles. After adopting the exclusion criterion by type of publication (reviews, research, book chapters and others), the number of articles was limited to 10,419. After that, 10,268 articles were excluded by title and abstract and only 4 were excluded for repetition, resulting in 147 articles. Finally, an additional article (Diniz *et al.*, 2018) previously known to the authors and of interest for this study was included. The total number of articles included in the qualitative summary was 148. This selection process was illustrated in Figure 1. The Figure 2 presents publications by year of publishing. In blue were illustrated publications during the first 25 years (between 1964 and 1989); in orange, between 1990 and 1999; in green, between 2000 and 2009; in red, publications from the last decade (from 2010 to 2019); and, separately, in gray, the publications of 2020, since the year of 2020 has not yet ended and this number will probably increase until its end. In total, 32 years of publication were recorded and the year of 2019 is the one with the highest number of publications. In figure 3, publications were presented according to their type. Research articles were the vast majority and represented 75 studies. This was followed by book chapters, which represented 41 studies. The review articles were in the third place and represented 20 articles.

The fourth group had 12 studies and was classified as "others", which represented encyclopedias, discussions, editorials, mini reviews, practical guides, conference summaries, errata. Figure 4 shows where the studies were published. The journals with a higher number of publications (>3) were illustrated separately, while those with less or published in books were grouped under the column "Others". Figure 5 shows the publications by country of origin, representing 26 countries in addition to the countries of the European Union (articles from Greece, Spain, Italy, Germany, United Kingdom, Finland, Denmark, Portugal, Belgium, Norway, France, Sweden, and Croatia). The European Union published most articles, in total 43.
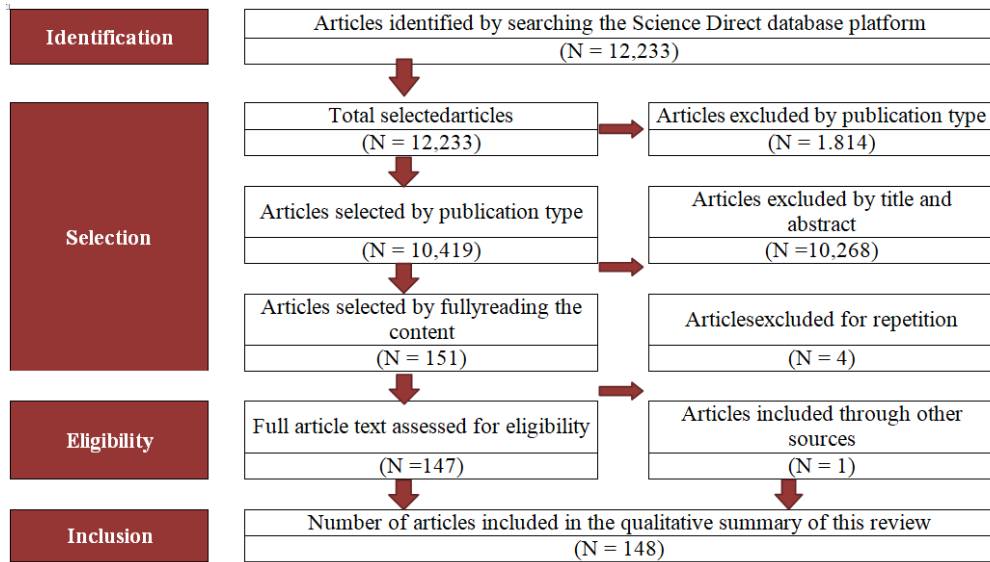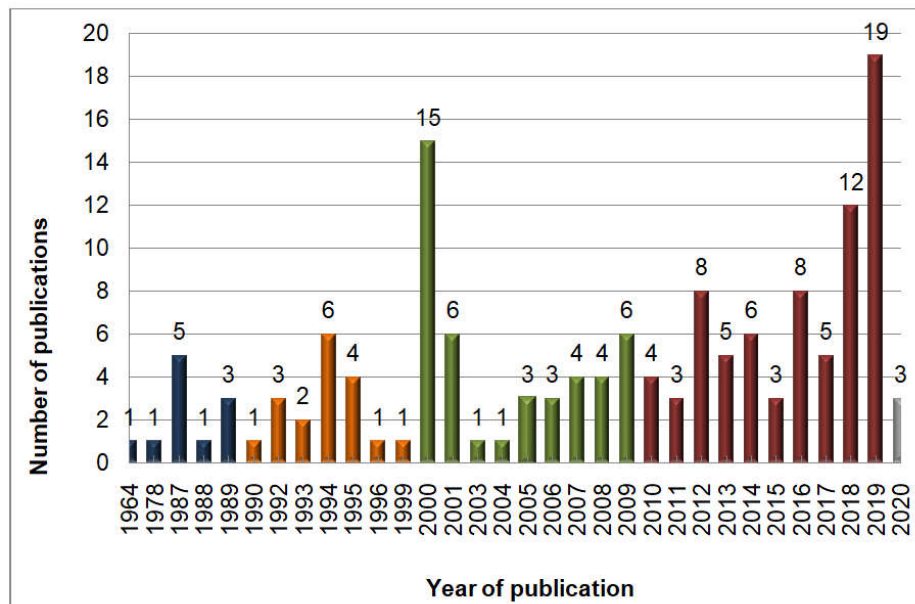
Figure 1: Flowchart Prisma Methodology

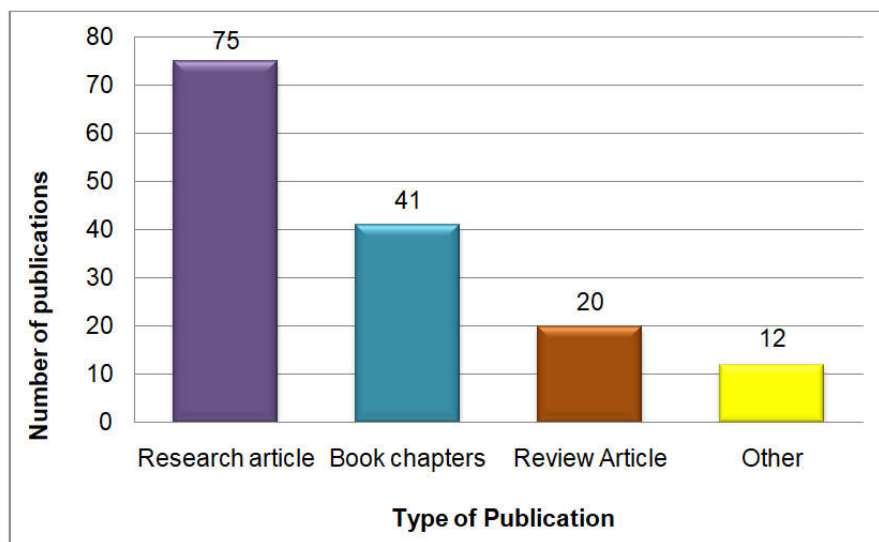**Figure 2. Publication Distribution per year**
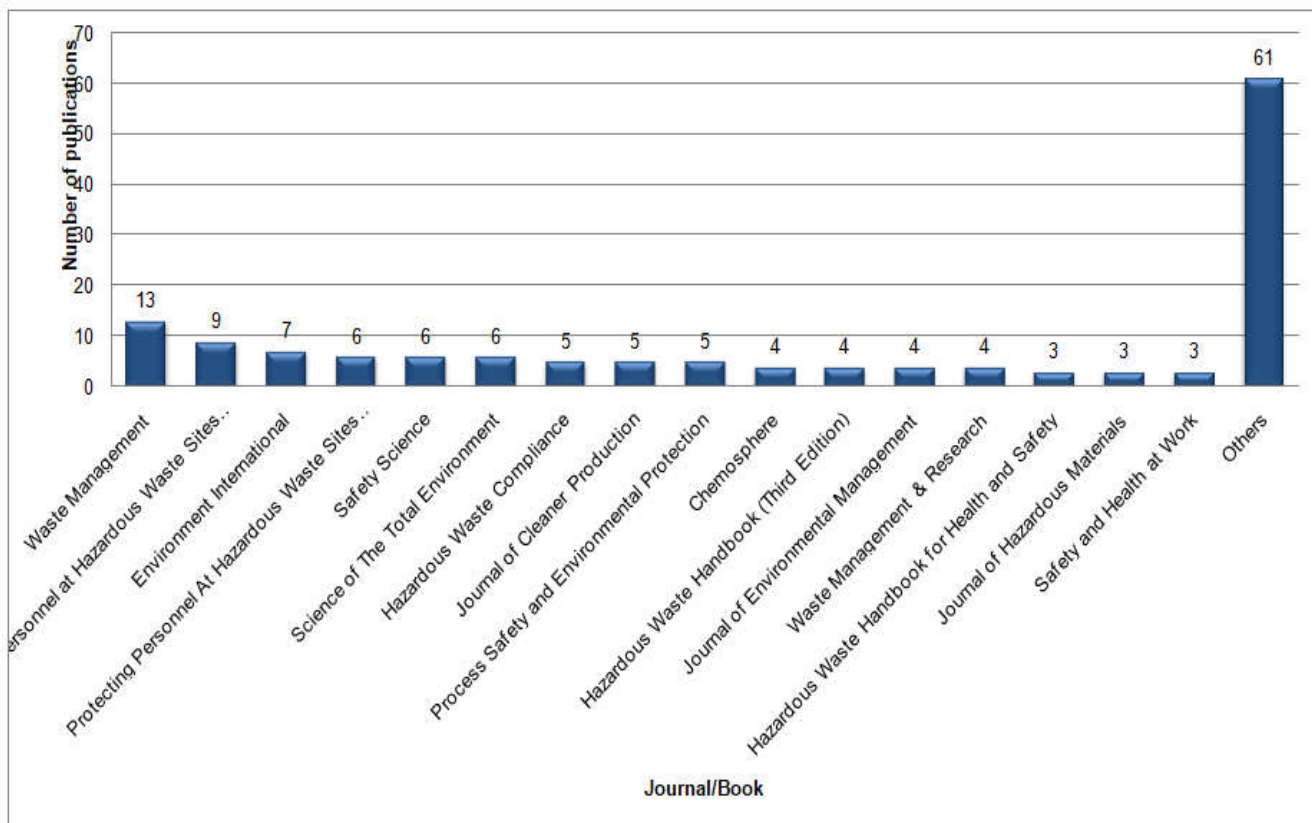
Figure 3: Publication Distribution by type

Figure 4. Publication Distribution by Journals in which were published
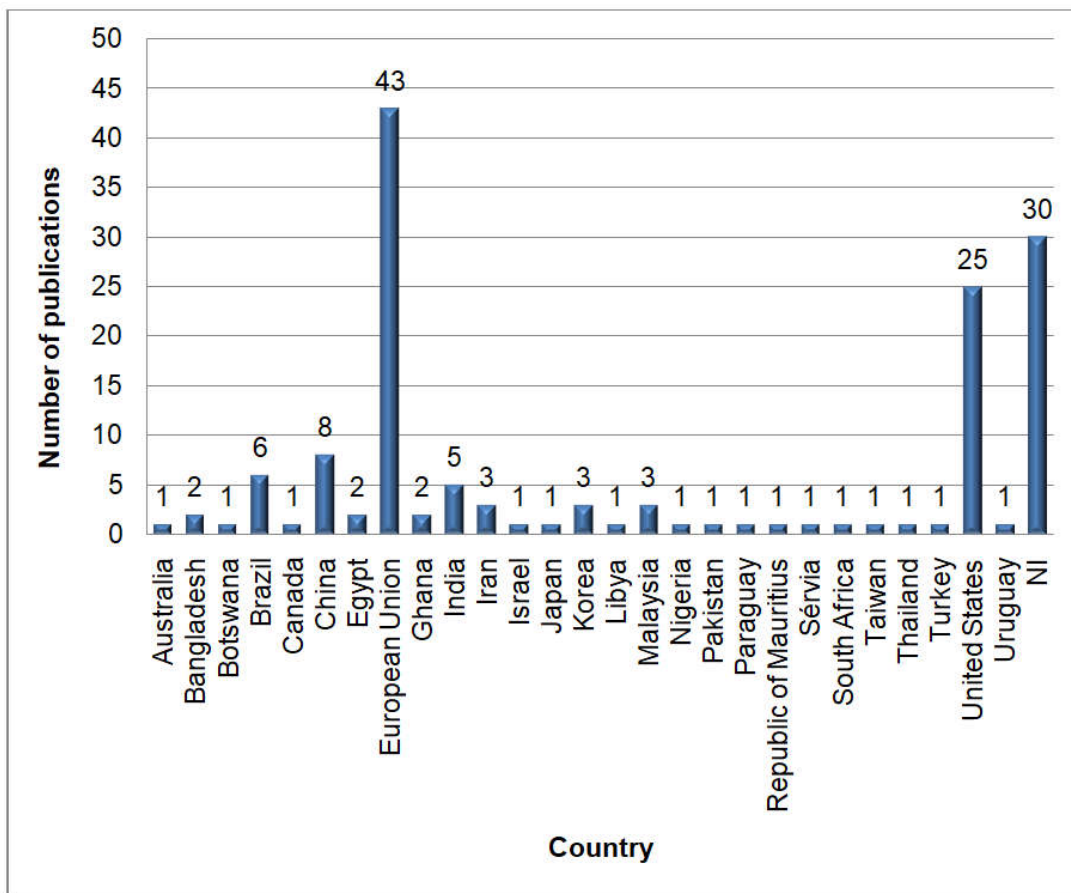

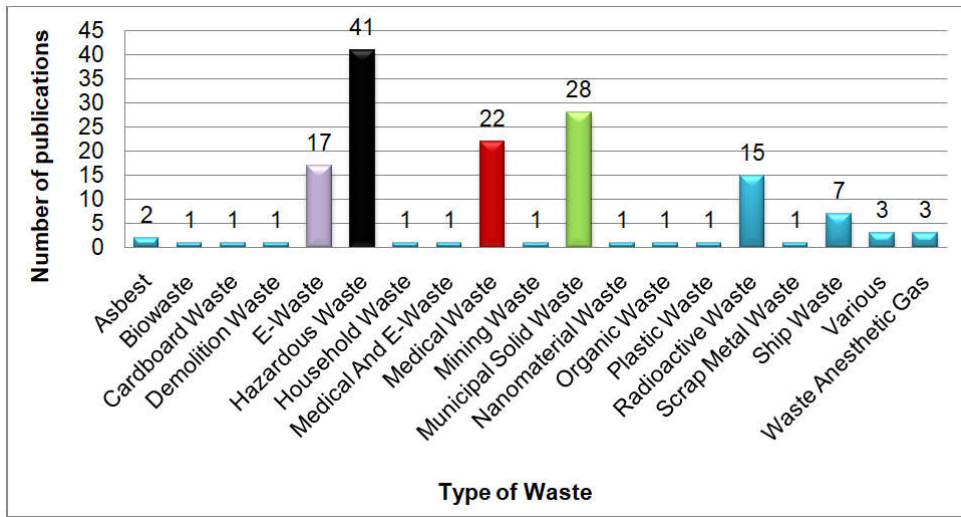**Figure 5: Publication Distribution by Country**

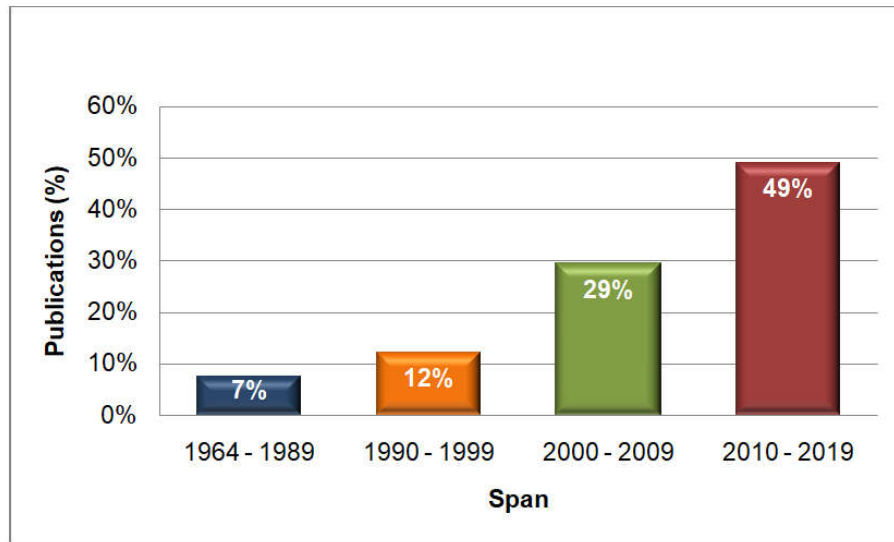**Figure 6. Publication Distribution by Type of Waste**

Figure 7. Graph of published studies vs. time intervals
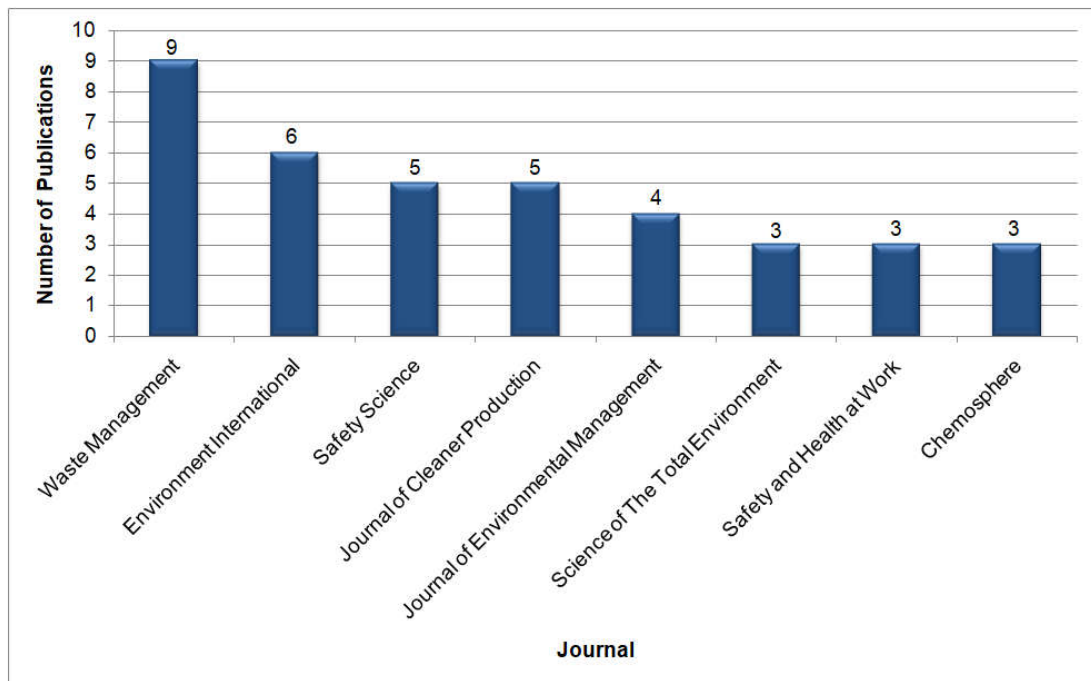

Figure 8. Publication Distribution by types of publication in the last decade (2010-2019)
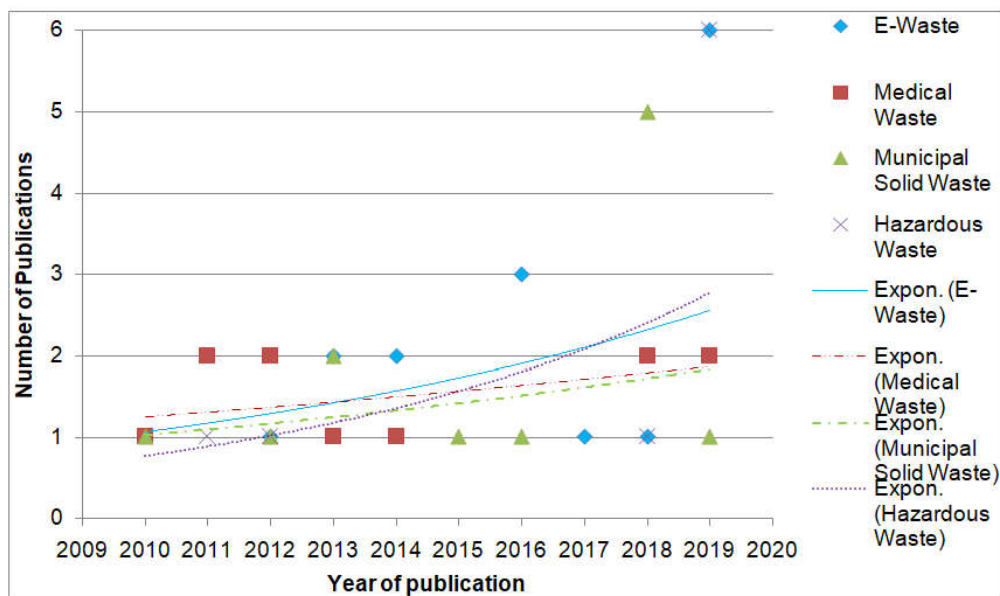
Figure 9. Publication Distribution in the last decade (2010-2019) according to the types of waste

Some countries were not identified in the search and, therefore were classified as NI (not identified). In Figure 6, the studies were illustrated by the categories of waste analyzed by the publications. These wastes were classified into 19 categories, and Hazardous waste was the most addressed type in publications. The "Various" category includes waste other than those previously classified or the combination of two or more of these.

DISCUSSION

In total, 32 years of publication were recorded and divided into four groups. Most publications were during the years 2019 (19 publications), 2000 (with 15 publications), 2018 (with 11 publications) and 2012 and 2016 with 8 publications each. From these five years, it can be seen that only the year 2000 belongs to the previous decade. This could be explained with the fact that during the past decade, more attention is given to waste generation and management and questions as how to preserve the environment at a global level during the turn of the millennium. For example, The United Nations launched at the Millennium Summit, that took place in the United States in 2000, the 8 Millennium Development Goals. Among them, the number 7 objective, Quality of Life and Respect for the Environment, stands out the problem that without the adoption of environmental policies and programs, nothing is properly preserved in nature. This may have influenced the creation of policies in several areas of the environmental sphere, including waste regulations in different countries (United Nations, 2018). In order to have a macro temporal perception of the studies, the years of publication were grouped into four categories, as shown in Figure 7. In the first block were the publications referring to the 1960s, 1970s and 1980s, while the subsequent blocks refer to the 1990s, 2000s and 2010s decades, respectively. It is noted it has been an increase in the number of publications over the decades, indicating that the concern has increased over the years. Despite the first block covers the longest time span, 25 years, it represents fewest publications, while the last block, relative to the decade of 2010, represents almost 50% of all included publications.

In order to have a macro temporal perception of the studies, the years of publication were grouped into four categories, as shown in Figure 7. In the first block were the publications referring to the 1960s, 1970s and 1980s, while the subsequent blocks refer to the 1990s, 2000s and 2010s decades, respectively. It is noted it has been an increase in the number of publications over the decades, indicating that the concern has increased over the years. Despite the first block covers the longest time span, 25 years, it represents fewest publications, while the last block, relative to the decade of 2010, represents almost 50% of all included publications. Referring to the types of publication, the studies were published in 67 journals/books. In decreasing order of number of publications, these journals/books were also classified into four groups. In first position is the Waste Management Journal with 13 articles. Next is the book Protecting Personnel at Hazardous Waste Sites (Third Edition) with 9 published chapters, which directly influenced the distribution of publications by year in Figure 2, which points out that the year 2000 was the second one with more publications, only behind of the year 2019. Right after, in third position, is the Environment International Journal, with 7 articles. The fourth placing was occupied by two journals and one book, Science of the Total Environment Journal, Safety Science Journal, and Protecting Personnel at Hazardous Waste Sites (Second Edition), with 6 publications each. Among the countries which publish the most, it was observed that the European Union is in the first place, with 41 published studies, followed by the United States with 24, and China with 8. In fourth place is Brazil with 6 published studies. This does not mean that these are the only studies published by these countries, since the search on the Science Direct platform was carried out with keywords in the English language. Thus, countries whose official language is not English may have not been included and published in a different language and consequently may have a greater number of publications than it was considered by the present study. For decades, the European Union has been working vigorously in the formulation of environmental protection standards, showing that this is one of its main priorities (Damacena, 2011). European environmental management laws and models have been and still are worldwide references.

The Brazilian National Solid Waste Policy, for example, is based on current concepts used in developed countries, particularly in Europe (Mannarino, Ferreira and Gandolla, 2016). In spite of producing a large amount of waste, the United States has been showing some concern about the management of its waste over the past century. According to (Eigenheer, 2009) there are reports in the middle of the 18th century that the selective garbage collection started in the United States and only later reached Europe. Years later, in the first half of the 20th century, Americans pursued a more adequate destination to the waste, and it was deposited in the so-called "sanitary landfills". Cavities were used on the ground to deposit the residues that were covered by soil afterwards, restricting insect proliferation and bad smell. However, no records were regarding the protection of the safety and health of workers while performing their tasks.

In relation to the waste categories, these were classified into 19 types. The 4 most expressive groups were Hazardous Waste, with 41 publications; Municipal Solid Waste with 27 publications; Medical Waste with 22 publications; and E-waste with 17 publications. The Hazardous Waste classification includes several types of waste, however, in this research, the most common were chemical, radioactive and industrial waste. The term "dangerous" has been used differently in several countries. In the USA, it defines hazardous wastes with physical, chemical, or infectious characteristics that require special handling and disposal procedures to avoid risks to human health and/or other environmental effects (US EPA, 2005). In Germany, the term "special waste" is used instead of "hazardous waste". The technical definition for these wastes is that due to their nature, composition, or quantity, they are especially hazardous to the health, for the air or water quality, besides being explosive, flammable, or can promote infectious diseases. Therefore, special requirements are required for their control (Dowling, 1985). According to Figure 9, that illustrates publications from the last decade with the four main types of waste, it is noticed that the category of Hazardous waste was not computed in all years. The increase of the concern with this type of waste may have influenced the decrease in the production of these contents.

The World Health Organization (WHO) designates Medical Waste (MW) or Health-care waste those generated by healthcare activities that can include a wide range of materials, such as used needles and syringes, dirty bandages, body parts, diagnostic samples, blood, chemicals, pharmaceuticals, drugs, devices, and radioactive materials (World Helath Organization, 2007). In the last decade (see Figure 9), this category of waste was more present than Hazardous Waste, indicating that hospital waste management has been a more frequent concern among scholars. Municipal solid waste (MSW) are those collected throughout the municipal perimeter. However, the most common is the collection of common/household waste. Vulgarly called garbage, it consists of everyday items, such as product packaging, ornaments, furniture, clothing, bottles, cans, food, newspapers, appliances, electronics, and batteries. Sources of MSW include residential waste (including waste from multifamily housing) and waste from commercial and institutional locations, such as businesses, schools, and hospitals. This definition of MSW from the Environmental Protection Agency (EPA) does not include industrial, hazardous, or construction and demolition (C&D) waste. Once generated, the MSW must be collected and managed by municipal agencies and managers. Common management methods include recycling, composting, energy recovery combustion, and landfill. Many wastes deposited in landfills represent a loss of materials which can be reused, recycled, or converted into energy to replace the use of virgin materials (US EPA, 2017a). The number of municipal waste studies increased during the last ten years. In the fourth position were the E-waste, those originated from discarded electrical devices and electronic components. Electronic waste are considered to be devices destined for repair, reuse, resale, and recycling through the recovery of materials or disposal itself (World Helath Organization, 2007). Figure 9 shows the distribution of the number of publications over the last decade (2010-2019) with exponential trend lines created according to the types of waste studied, and reveals how much the number of these publications has evolved over the past ten years. Thus, it is observed that publications on E-waste increased considerably during the past years, especially in 2019. The beginning of the current century was marked by technological advances in several aspects, including the reformulation of materials and processes, such as the production of nanomaterials.

As the name suggests, they are very small materials, measuring from 1 to 100 nanometers, with high performance properties and diverse applications, composing faster and more efficient products and electronics (European Comission, 2011). With a global market of around 11 million tons, nanomaterials already are very competitive in the financial market and have a growth tendency from a billion-dollar market in 2009 to a trillion-dollar one in 2015. In Europe, this market employs around 350 thousand people (European Comission, 2017). Despite this massive use, these materials can cause harm to human health. The European Agency for Safety and Health at Work (EU-OSHA) reveals that the health effects of nanomaterials have already been found in the lungs, with the inflammation and tissue damage, fibrosis and tumor generation, and can be absorbed by secondary organs, including brain, kidney, liver, among others. Some types of carbon nanotubes can also lead to effects similar to asbestos (International Labour Organization, 2019). However, still there is a need for detailed studies on the effects of such innovative materials on human health and the environment (Yu *et al*., 2015). Therefore, research should be developed not only with greater information on the specificities of these substances, but also on strategies for collection, recycling, transportation, final destination, and treatment of waste generated from this type of product in order to protect the population's health as well as the environment.

Conclusion

Through the systematic review, the present work detected 148 studies associated with waste management and occupational safety in four different publication formats: book chapter, research article, review and others. The articles represented the main type of publications. In total, 32 years of research were identified, with publications getting more frequent in the last decade, mainly relating to e-waste, hazardous waste, medical waste, and municipal waste. In 2000, there was a sharp increase in the number of publications, increasing even more during the past decade, which can be explained with the increased global concern with the environment and human health. In general, hazardous waste was the most frequently considered type of waste. However, e-waste has also been quite prominent during the last decade. Regarding the type of publication, research articles were the most present format.

The European Union was the one publishing most studies, followed by the United States, China, and Brazil, respectively.

REFERENCES

BRASIL 2010. 'LEI No 12.305, DE 2 DE AGOSTO DE 2010 - Política Nacional de Resíduos Sólidos'. Brasília: Presidência da República.

Damacena, F. 2011. 'A Proteção Ambiental no Âmbito da União Européia', Revista Eletrônica Direito e Política, 61. . Available at: www.univali.br/direitoepolitica.

Diniz, N. *et al*. 2018. 'Segurança do Trabalho, Produtividade e Qualidade: Análise da Coleta de Resíduos Sólidos Urbanos', in. Maceió, Alagoas: XXXVIII ENCONTRO NACIONAL DE ENGENHARIA DE PRODUCAO.

Diniz, N. *et al*. 2019. 'Work-Related Accidents in Urban Solid Waste Collection', Occupational and Environmental Safety and Health, 202, pp. 701–709. doi: 10.1007/978-3-030-14730-3.

Dowling, M. 1985. 'Defining and classifying hazardous wastes', Environment, 273. , pp. 18–41. doi: 10.1080/00139157.1985.9930823.

Eigenheer, E. M. 2009. 'A História do Lixo: a limpeza urbana através dos tempos', p. 144. Available at: http://www.lixoeeducacao.uerj.br/imagens/pdf/ahistoriadolixo.pdf.

European Comission 2011. 'Recomendação da Comissão de 18 de Outubro de 2011 sobre a definição de nanomaterial', Jornal Oficial da União Europeia, 2005. , pp. 2010–2012.

European Comission 2017. Nanomaterials. Available at: https://ec.europa.eu/growth/sectors/chemicals/reach/nanomaterials_en.

International Labour Organization 2019. Safety and Health at the Heart of the Future of Work, Building on 100 years of experience. Geneva, Switzerland.

Mannarino, C. F., Ferreira, J. A. and Gandolla, M. 2016. 'Contribuições para a evolução do gerenciamento de resíduos sólidos urbanos no Brasil com base na experiência Européia', Engenharia Sanitaria e Ambiental, 212., pp. 379–385. doi: 10.1590/S1413-41522016146475.

Nascimento, V. F. *et al*. 2019. 'Municipal solid waste disposal in Brazil: Improvements and challenges', International Journal of Environment and Waste Management, 233. , pp. 300–318. doi: 10.1504/IJEWM.2019.099007.

Nichols, W. and Smith, N. 2019. 'Waste Generation and Recycling Indices 2019 Overview and findings', Verisk Maplecroft, June. . United Kingdom.

Poulsen, O. M. *et al*. 1995. 'Sorting and recycling of domestic waste. Review of occupational health problems and their possible causes', Science of the Total Environment, 1681. , pp. 33–56. doi: 10.1016/0048-969795. 04521-2.

US Environmental Proctection Agency 2005. 'Hazardous Waste Identification 40 CFR Parts 261. ', Solid Waste and Emergency Response, EPA530-K-0September. . Washington, D.C., EUA.

US Environmental Proctection Agency 2017a. Municipal solid waste, Energy Conversion, Second Edition. doi: 10.1201/9781315374192. Washington, D.C., EUA.

US Environmental Proctection Agency 2017b. National Overview: Facts and Figures on Materials, Wastes and Recycling. Washington, D.C., EUA. Available at: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials#:~:text=MSW%20generation%20per%20person%20per,67%20million%20tons%20in%202017.

United Nations 2018. Target 7. A : Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources Target 7. B : Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of. New York, NY, EUA. Available at: https://www.un.org/millenniumgoals/environ.shtml.

World Health Organization 2007. Health-care waste, Health topics. Geneva, Switzerland. Available at: https://www.who.int/topics/medical_waste/en/.

Yu, I. J. *et al*. 2015. 'Occupational and environmental health effects of nanomaterials', BioMed Research International, 2015, pp. 2–4. doi: 10.1155/2015/789312.

****