

# Bibliometric analysis in databases on publications related to the replacement of natural aggregates by residues with a focus on sustainability and Brazil

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## Research Article

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# Abstract

As part of a research project on the substitution of natural aggregates for residues, this article carried out a literature review, identifying articles that have the words aggregates, residues and concrete in their topics, in the Scopus and Web of Sciences bases. Among the main objectives of this review are: to verify what is the relative position of Brazil in relation to research in the area of substitution of aggregate for waste; to identify the main residues that are being studied to be used as raw material substitutes in the construction industry, mainly in Brazil; evaluate the hypothesis that a search using the words concrete, aggregate and residue will result in articles from the environmental and civil engineering areas. The main results are: Brazil is the country that most published articles with the characteristics investigated in the present work, followed by the countries China, Italy, USA and Spain; articles by Brazilian authors are predominantly from the areas of engineering and the environment; there are several studies investigating the substitution of natural aggregates for residues, mainly the substitution for residues of the civil construction itself; in Brazil, the most investigated residues to be used as raw material substitutes for the civil engineering industry are the residues of the civil engineering industry and the residues of agricultural products. The result of the review also identified the need for an improvement in the data and research tools of the databases used. The reasons are the probable data inconsistencies and flaws in the research tools found in the databases. With all these results, this work intends to provide basic information for researchers who intend to initiate research on the substitution of natural aggregates for waste, in addition to using them to continue the research project of replacing part of natural aggregates with electronic waste in the production of concrete. It also intends to show the importance of revision work for the improvement of data and database tools.

## 1 Introduction

Various actions, such as the increase in the number of Universities and Institutes with a focus on sustainability, contribute to infer that the commitment to sustainability is growing in the world (Khalili et al., 2015). This increase has produced improvements in some environmental indicators in recent decades. However, empirical data shows that the global increase in energy and raw material consumption has put pressure on the environment (Askham et al., 2012), mainly due to the exponential increase in the exploitation of natural resources observed in the last decades. (Gómez-Baggethun & Naredo, 2015). Along with the increase in the consumption of natural resources, the generation of waste is also a negative factor for sustainable development. Thus, the use of waste as a raw material contributes to sustainable development, since this practice has the main benefits of reducing environmental pollution and conserving natural resources (Onuaguluchi & Panesar, 2014).

The construction industry is largely responsible for extracting resources from nature, and today it is the largest consumer of limited natural resources, including sand, water, rocks and gravel (Mefteh et al., 2013). Many natural aggregates used in concrete are dug out of maritime mats, riverbeds, mines and other natural geological structures (Khankhaje et al., 2016). These activities cause irreparable damage to

the environment due to the destruction of the geological structure and the contamination of the soil, air and water (Khankhaje et al., 2017).

In view of what has been exposed so far, this work understands that a way to contribute to lessen the negative impacts to nature, caused by the construction industry, is to replace part of the natural aggregates with residues in the production of concrete. As an initial step in this project, a literature review was carried out, with the following objectives:

- Identify the profile of the articles with the words aggregates, residues and concrete in the title, abstract or keywords, in the Scopus and Web of Science databases and with Brazilian authors; and
- Obtain basic information on the types of waste under investigation to replace natural aggregates, mainly in Brazil.

When obtaining this information from the literature review, this present work intends to provide basic information for researchers who intend to initiate research on the substitution of natural aggregates for residues. Another objective is to use this data to continue this project, investigating the use of electronic waste as a substitute for part of natural aggregates in the production of concrete.

In the course of this research, possible inconsistencies in the data and results provided by the tools used were identified. When identifying these possible inconsistencies, the objective of this work also became to contribute to the improvement of the information provided by the databases used, in addition to demonstrating the importance of literature review works to give the bases reliability and correct any information errors.

## 2 Methodology

On 09/30/2020 a survey was carried out on the Scopus base. In this research, articles were selected that had the words aggregates, residues and concrete in the title or keywords, or in the abstract. The same process was carried out on the Web of Sciences database, on 10/07/2020. With the research data, graphics were produced that shows the distribution of articles by year of publication, by country and by subject area.

After analyzing the results of the information obtained so far, this work quantitatively analyzed the data related to articles in the environmental areas. The reason is that these are the areas of interest of this present work. These analyzes produced graphs showing the distribution of articles by year of publication and country of the authors.

As one of the objectives of this work is to identify the profile of these articles with Brazilian authors, graphics were produced that presented the following data: distribution by year of publication; distribution by thematic area; distribution, by year of publication, of articles with Brazilian authors in the environmental area; types of waste studied; graphics showing the occurrence of the words investigated

here in the title, abstract or keywords; and finally, a table with the most relevant information from the articles analyzed here.

## **3 Results**

### **3.1 Scopus Base**

In the Scopus database, 371 articles were identified containing the words aggregates, residues and concrete in the title or in the keywords or in the abstract. Figure 1 shows the distribution, by year of publication, of these articles.

Figure 2 shows the 20 countries that most published articles with the words aggregates, residues and concrete in the title or in the keywords or in the abstract. It is worth mentioning that the Scopus Base was unable to identify the country of origin of 41 articles.

Figure 3 shows the distribution of the 371 articles in the Scopus database by subject area.

Figure 4 shows the distribution, by country, of the 99 articles found in the Scopus database that have the words aggregates, residues, concrete in the title or in the keywords or in the abstract and which are from the Environmental Science subject area.

Figure 5 shows the evolution of the number of publications of articles in the Environmental Science subject area in the Scopus database.

Figure 6 shows the summary of the main information for the article data in the Scopus database.

#### **3.1.1 Data about articles with Brazilian authors**

Figure 7 shows the distribution, per year, of Brazilian publications with the words aggregates, residues and concrete in the title or abstract or in the keywords.

Figure 8 shows the distribution of articles by Brazilian authors by subject area.

Figure 9 shows the number of articles, published per year, by Brazilian authors in the Environmental Science in the Scopus database.

Figure 10 shows the summary of the main information for the article data with Brazilian authors in the Scopus database.

### **3.2 Web of Science Base**

Figure 11 shows the distribution, by year of publication, of articles with the words aggregates, residues and concrete in the title or in the keywords or in the abstract, in the Web of Science database.

Figure 12 shows the distribution, by subject area, of the articles identified in the Web of Science database with the same characteristics as the articles researched in the Scopus database.

Figure 13 shows the number of publications, distributed by country in the Web of Science database.

Figure 14 shows the distribution, by year of publication, of articles in the Science Ecology Environmental subject area.

Figure 15 shows the distribution, by country, of articles in the Environmental Science area.

Figure 16 shows the summary of the main information for the article data on the Web of Sciences.

### **3.2.1 Data about articles with Brazilian authors**

Figure 17 shows the distribution, by subject area, of articles that have the words aggregates, residues and concrete in the title or keywords or in the abstract in the Web of Science database.

Figure 18 shows the distribution, by year of publication, of articles that have Brazilian authors.

Figure 19 shows the distribution, by year of publication, of articles by Brazilian authors in the subject area Sciences Ecology Environmental.

Figure 20 shows the summary of the main information for article data with Brazilian authors in the Web of Sciences database.

### **3.2 Environmental articles with Brazilian authors**

Chart 1 shows the main information from articles in the environmental areas with Brazilian authors. As can be seen in Chart 1, the total number of articles identified was 35. This quantity is different from the sum of the articles identified in the Web of Science database, which was 33, with the number of articles identified in the Scopus database, which was 8. This is due to the fact that five articles are in the two bases.

<b>Frame 1: Main information of articles with Brazilian authors</b>				
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Coppio et al., 2019)			Construction and Building Materials	Experimental Research
Words aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
concrete, aggregate, waste	concrete, aggregate, waste	Concrete	To study the effects of using foundry sand as a fine aggregate of the concrete mixture on the compressive strength and surface electrical resistivity.	Compressive strength tends to decrease with the use of residual casting sand as a fine aggregate.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Rangel et al., 2019)			Journal of Cleaner Production	case study
Words aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
concrete, aggregate,	concrete, aggregate, waste	concrete, aggregate, waste	To find a possible relationship between the origin of the waste and the characteristics of the resulting recycled aggregate concrete.	Using the waste classification proposed in the work can promote the complete reuse of waste in different cement products.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(dos Anjos et al., 2017)			Journal of Environmental Management	Experimental Research
Words aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
concrete, aggregate,	concrete, aggregate, residue	concrete, waste	Evaluate the effects of total and partial replacement of fine aggregate with blasted copper slag and abrasive blasting residue on Portland cement structural concrete.	Despite the tensile strength of the concrete decreased with the increase of the sandblasted copper slag content, the work concludes that total or partial replacement of the natural fine aggregates by this residue may be viable.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>

(Amorim Júnior et al., 2018)			Construction and Building Materials	Experimental Research
Words aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
concrete, aggregate,	concrete, aggregate,	aggregate, residue	Check the influence of the recycled aggregate on the durability of the concrete subjected to the freezing and thawing cycles.	The use of recycled aggregates proved to be efficient as a possible alternative to the incorporation of air in the concretes, presenting a durability factor at the end of the cycle higher than that presented by the reference mixture.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Lima & Iwakiri, 2014)			Ciência Florestal	Experimental Research
Palavras aggregate, residue and concrete			Objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
concrete, aggregate, residue	concrete, aggregate, residue	concrete, aggregate,	To evaluate the substitution of fine aggregate for waste from the splitting of logs of Pinus spp in the production of structural masonry blocks.	Satisfactory results were obtained by replacing up to 50% of the mineral fine aggregate with the Pinus spp.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(da Silva et al., 2020)			Waste Management & Research	Experimental Research
Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
aggregate	aggregate, residue	aggregate, residue	Evaluate the carbonation process by replacing part of the fine aggregate with granite residue in the production of mortar.	The exposure time variable was found to have a greater influence on the carbonation process. Under the conditions analyzed, the granite residue proved to be beneficial, reducing the carbonation depth.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Luis de Oliveira Júnior et al., 2019)			Journal of Building Engineering	Experimental Research

Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
aggregate, residue	residue aggregate, waste	residue, waste	To evaluate the effects of partial replacement of the natural sand aggregate of an ecological mortar by different percentages of grain residue on the compressive, flexural and tensile strength of the material.	The results indicate a potential for the use of this residue as a partial replacement of fine aggregates in coating mortars and suggest that 15% can be considered the ideal replacement ratio.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Bacarji et al., 2012)			Key Engineering Materials	Experimental Research
Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
concrete, waste	concrete, aggregate, residue, waste	concrete, waste	To study the use of natural sand by two mineral residues in the production of concrete.	It has been demonstrated that it is possible to obtain self-compacting structural concrete, self-compacting concrete without structural purpose and conventional concrete using mineral residues instead of natural aggregates.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Castro Mendes et al., 2020)			Journal of Material Cycles and Waste Management	Experimental Research
Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
Residue	aggregate, residue	Residue	Check the feasibility of using mining and industrial residues as aggregates of coating mortars in terms of the thermal performance of buildings.	Mortars produced with mining and industrial waste can be economical and sustainable solutions to passively improve the thermal performance of buildings, as well as mitigate the impacts of the disposal of this waste.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Favaretto et al., 2017)			Applied Sciences-Basel	case study
Palavras aggregate, residue and			objectives	Main Conclusions or

concrete			Proposals	
Title	Abstract	Keywords		
concrete, waste	concrete, aggregate, residue, waste	concrete, waste	Evaluate the use of construction and demolition waste (WCD) from the Passo Fundo region, Rio Grande do Sul (RS), Brazil, in the development of aerated concrete foam.	WCD residues from the study region can be used as aggregates for the development of aerated concrete foam. However, it must be characterized before being used to guarantee the quality of the final product.
<b>Article</b>		<b>Journal</b>		<b>Methodology</b>
(Zerbino et al., 2011)		Construction and Building Materials		Experimental Research
Palavras aggregate, residue and concrete		Objectives		Main Conclusions or Proposals
Title	Abstract	Keywords		
concrete	concrete, aggregate, residue	concrete, waste	Use rice husk ash without any grinding (in natura) to replace part of the structural concrete aggregates.	The incorporation of natural rice husk ash (without grinding) in the structural concrete represents a good alternative for the disposal of this residue, even without the previous optimization through a grinding process.
<b>Article</b>		<b>Journal</b>		<b>Methodology</b>
(Afonso et al., 2013)		Applied Mechanics and Materials		Experimental Research
Palavras aggregate, residue and concrete		objectives		Main Conclusions or Proposals
Title	Abstract	Keywords		
	concrete, aggregate, residue		Evaluate the incorporation of sludge in the concrete used in the manufacture of concrete blocks.	Blocks were obtained that are classified with structural function, for use in above ground masonry elements, according to the Brazilian standard.
<b>Article</b>		<b>Journal</b>		<b>Methodology</b>
(Caetano et al., 2020)		Clean Technologies and Environmental Policy		Experimental Research
Palavras aggregate, residue and concrete		objectives		Main Conclusions or Proposals
Title	Abstract	Keywords		

concrete, residue	concrete, aggregate, residue, waste	concrete, residue, waste	To characterize the fine fraction of RCA (automotive crushing residue) generated in a plant located in Brazil. It is also proposed to recycle concrete blocks for paving to replace the natural fine aggregate using the Portland cement solidification / stabilization technique.	The concrete paving blocks showed good mechanical and physical performance. Therefore, the produced concrete paving block can be used as a potential solution to mitigate the environmental impact caused by the fine fraction of RCA waste.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Pelisser et al., 2011)			Journal of Cleaner Production	Experimental Research
Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
concrete	concrete, aggregate, residue	Concrete	To Investigate the potential for using recycled tire rubber in cement matrices.	Rubberized concrete can support the sustainability of construction, minimize the consumption of natural resources with the use of industrial waste and produce a material with special characteristics.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Granzotto & Souza, 2013)			Acta Scientiarum-Technology	Experimental Research
Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
concrete, aggregate	concrete, aggregate, waste	Residue	Analyze the behavior of the concrete produced with different proportions of substitution of fine aggregate by rubber waste tires.	Experimental results revealed that additions of rubber of up to 5% in substitution to sand can produce concretes with medium compressive and tensile strength similar to that obtained for normal strength concrete.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Fioriti et al., 2010)			Acta Scientiarum-Technology	Experimental Research
Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals

Title	Abstract	Keywords		
concrete, residue	concrete, aggregate, residue	concrete, residue	Investigate the possibility of using waste tires as part of the raw material in the production of interlocking blocks.	Blocks interlocked with waste tires can be used in some environments such as sidewalks, squares, bike lanes and residential condominiums.
<b>Article</b>		<b>Journal</b>		<b>Methodology</b>
(Sales et al., 2010)		Construction and Building Materials		Experimental Research
Palavras aggregate, residue and concrete		objectives		Main Conclusions or Proposals
Title	Abstract	Keywords		
concrete	concrete, aggregate, residue	Concrete	Evaluate the potential of lightweight concrete produced by replacing part of the coarse aggregate with sawdust residue, together with sludge from water treatment.	The concrete of this study presented a set of thermal properties suitable for the application of this concrete in non-structural sealing elements.
<b>Article</b>		<b>Journal</b>		<b>Methodology</b>
(Paz & Santos, 2019)		Revista Eletrônica em Gestão Educação e Tecnologia Ambiental		Experimental Research
Palavras aggregate, residue and concrete		objectives		Main Conclusions or Proposals
Title	Abstract	Keywords		
concrete	concrete, aggregate, residue	Concrete	Analyze the mechanical performance of concrete produced with non-returnable packaging glass waste.	The concrete with the use of ground glass obtained an average resistance of 32.37 MPa. This result indicates a technical feasibility of using the waste.
<b>Article</b>		<b>Journal</b>		<b>Methodology</b>
(de Oliveira Andrade et al., 2018)		Journal of Cleaner Production		Experimental Research
Palavras aggregate, residue and concrete		objectives		Main Conclusions or Proposals
Title	Abstract	Keywords		
aggregate	aggregate, residue, waste	Aggregate	Investigate the mechanical properties (bond strength, compressive strength and flexural strength), durability	In general, this study showed that waste, as a source of fine mortar aggregates, can be

(water absorption) and microstructural analysis of coating mortars with different levels of substitution (2.5% by weight, 5% by weight, 7, 5% by weight and 10% by weight) of natural sand per aggregate of water treatment sludge.

considered a viable and sustainable alternative for use in the construction sector. The best result was obtained by replacing 5% of natural sand with sludge.

<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Copetti et al., 2020)			Journal of Cleaner Production	Experimental Research
Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
concrete	concrete, residue, aggregate, waste	Concrete	Evaluate the influence of a chemical pretreatment with sodium hydroxide solution (NaOH) on the physical, mechanical and microstructural properties of concrete with two levels of rubber residue (15% and 30%) as a natural substitute for fine aggregate, and the addition of silica fumes (7.5% and 15%) to replace Portland cement.	Although many factors still need to be investigated, it was found that the reuse of rubber residue in concrete without any pre-treatment has no significance in the investigated properties and avoids pre-processing costs and can contribute to an appropriate destination of this material.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Molin Filho, Longhi, et al., 2019)			Environment Development and Sustainability	Experimental Research
Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
	aggregate, residue	concrete, residue	Develop self-compacting mortars with partial replacement of sand by sugarcane bagasse ash (SBA).	With the replacement of 40% of sand by SBA, it was possible to reduce by up to 489 kg of the sand and 56 kg of cement, to produce one cubic meter of self-compacting mortar with sugarcane bagasse ash.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Reis & Jurumenha, 2013)			Materials and Structures	Experimental Research

Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
aggregate	aggregate, residue, waste		Examine the mechanical properties, resistance to compression and flexion, of polymeric mortars (PM) made with used foundry waste, that is, foundry sand impregnated with polymer as aggregate.	Recycled casting sand can be used very conveniently to produce PM and building materials of acceptable quality.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Canova et al., 2008)			Acta Scientiarum-Technology	Experimental Research
Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
concrete, aggregate, waste	aggregate, residue	Residue	To evaluate a coating mortar with tire waste.	The studied product is an alternative that contributes to the reduction of cracks in mortar coatings.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Almeida et al., 2015)			Construction and Building Materials	Experimental Research
Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
	aggregate, residue		Investigate the effect of SBAS (sugarcane bagasse ash) on mortar, specifically its resistance to compression, porosity, depth of carbonation and chloride penetration.	The substitution of natural sand by SBAS, mainly with a 30% content, can lead to the maintenance of mechanical properties, clogging of micropores and improvement of the durability of mortars, compared to a reference mixture.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Molin Filho, Colpini, et al., 2019)			Clean Technologies and Environmental Policy	Experimental Research
Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		

aggregate, residue	Residue	To characterize bottom, fly and mixed ashes, subjected to low cost processing, in order to better target its applicability in products for civil construction.	The fly ash sample, without late burning and with amorphous structural organization, meets the prerequisites for evaluating pozzolanic applications in partial replacement of cementitious materials.
<b>Article</b>		<b>Journal</b>	<b>Methodology</b>
(Tonet & Gorninski, 2013)		Construction and building Materials	Experimental Research
Palavras aggregate, residue and concrete		objectives	Main Conclusions or Proposals
Title	Abstract	Keywords	
concrete, waste	concrete, aggregate, residue waste	Concrete	To develop innovative polymeric composites produced with residues of industrial alumina, a by-product of the steel industry.
			Polymeric concrete made with recycled resin in this study showed compressive strength values between 65.4 and 80.2 MPa. This shows that it is possible to produce PC (Polymer Concrete) composites that meet the current needs of the civil construction sector using environmentally friendly materials, without compromising their properties.
<b>Article</b>		<b>Journal</b>	<b>Methodology</b>
(Durante Ingunza et al., 2018)		Construction and Building Materials	Experimental Research
Palavras aggregate, residue and concrete		objectives	Main Conclusions or Proposals
Title	Abstract	Keywords	
	Residue		It studies the performance of mortars with the addition of sludge ash from septic tank.
			The results show that the addition of sludge ash from septic tank improves the general condition of mortars, within the limits studied in this work, providing better performance in both the fresh and hardened state.
<b>Article</b>		<b>Journal</b>	<b>Methodology</b>
(Modolo et al., 2015)		Fuel Processing Technology	Experimental Research

Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
	Aggregate residue	Aggregate	Investigate the use of ash residue from forest biomass as aggregate in cement-adhesive shroud.	The use of this type of waste as a raw material in the production of cementitious-adhesive mortar provides environmental benefits with economic advantages for producers of adhesive mortars.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Rosado et al., 2019)			Waste Management	case study / Life cycle assessment
Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
Waste	Residue, waste	Waste	Assess the environmental performance of construction and demolition waste management (C&DW) in the PCJ Hydrographic Basin area, located in the State of São Paulo, Brazil, through an attributional Life Cycle Assessment.	In general, the results highlighted the advantages of recovering materials, especially those related to the recycling of steel, glass and plastic. In this sense, municipalities should invest in incentive programs for sorting on construction sites, improving the quality of recovered materials and increasing recycling rates.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Hackenhaar et al., 2019)			Sustainable Built Environment D-A-Ch Conference 2019 (SBE19 GRAZ)	case study / Life cycle assessment
Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
Waste	aggregate, residue, waste		Explore the basic premises in proposing a product system for the recycling process for RCD (construction and demolition waste) in Brazil.	The identification and availability of information about the representation of RCD recycling in the Brazilian economic scenario can, together with the inventory of other information, corroborate

				with the elaboration of market data for Brazil.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Carvalho et al., 2017)			Resources, Conservation & Recycling	Experimental Research
Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
	Waste	Residue	Evaluates the partial replacement of blast furnace slag by slag slag from the basic oxygen furnace in the production of Portland cement.	The cement with the addition of oxygen oven slag obtained initial and final strength gains for all replacement levels. The use of oxygen furnace slag as a partial replacement for blast furnace slag proves to be a technical, economical and environmentally viable alternative for the cement industry.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Borges Marinho et al., 2017)			Journal of Materials in Civil Engineering	Experimental Research
Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
	Waste	Waste	Develop a sustainable binder obtained from LFS (ladle furnace slag), a by-product of secondary steel refining, replacing hydraulic lime.	The results obtained indicate the technical feasibility of using LFS as a binder for mortar to replace lime.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Mizobata et al., 2017)			Ciência Florestal	Experimental Research
Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
Residue	Residue		Evaluate the growth of Dipteryx alata (baru) and Astronium fraxinifolium (gonçalo-alves) seedlings in degraded soil, compacted or not, supplemented with agroindustrial residue and	The agro-industrial residue influenced the chemical conditions of the degraded soil, increasing the pH and the contents of K, Ca and Mg, and can be used as a soil conditioner;

			check the possibility of using it as soil conditioner.	Dipteryx alata had the fresh root mass negatively influenced by compaction and was undemanding in relation to the addition of nutrients.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Martins & Altoé, 2015)			Revista em Agronegócio e Meio Ambiente, Maringá (PR)	Experimental Research
Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
concrete	concrete, aggregate, residue		To study the use of sugarcane bagasse ash (SBA) in the replacement of fine aggregate in the manufacture of concrete paving blocks (pavers), subject to light stresses.	SBA proved to be a viable residue for the partial replacement of fine aggregate in the manufacture of pavers as it presents an expressive improvement of the analyzed characteristics (resistance to compression, absorption and abrasion) in relation to pavers manufactured without the partial replacement of sand by SBA.
<b>Article</b>			<b>Journal</b>	<b>Methodology</b>
(Garcia et al., 2018)			Sustentabilidade em Debate	Experimental Research
Palavras aggregate, residue and concrete			objectives	Main Conclusions or Proposals
Title	Abstract	Keywords		
concrete Aggregate Residue	concrete, aggregate, residue	Residue Aggregatr	Analyze the use of concrete block residues to replace mineral aggregates in asphalt paving of the hot machined bituminous concrete.	The results showed that composites with substitutions of mineral aggregates, up to 40% by mass, meet the established requirements and can be used in asphalt paving.

Figure 21 shows the occurrence of the words investigated by this work in the title.

Figure 22 shows the occurrence of the words investigated by this work in the abstract.

Figure 23 shows the occurrence of the words investigated by this work in the keywords.

Figure 24 shows the types of waste, which were studied as substitutes for raw materials in the construction industry, for the articles provided by the base tools.

## 4 Discussion

### 4.1 Global considerations

The results show that 371 articles were found in the Scopus database and 401 in the Web of Sciences database with the characteristics investigated by this present work. The first article with these characteristics identified in the Scopus database was published in 1963. In the Web of Sciences database, it was in 1996. The trend in the annual evolution of publications is similar in both bases (Figs. 1 and 11), showing a trend of increase in the number of publications since 2006. Both bases also have their peak of publications in 2019. It is important to note that the data for 2020 refer to 09/30/2020 for the Scopus database and until 10/07/2020 for the Web of Science database. Thus, it is very likely that the peak of publications will be the year 2020, confirming the trend of increasing publications in both bases.

When analyzing the distribution of articles by country, it appears that in both bases, Brazil is the country that most published articles with the characteristics investigated in this work, both in the Scopus database and in the Web of Sciences database. Here is an observation of what is probably an inconsistency in the Web of Science base, in relation to publications by Brazilian authors. The observation is that on the day of the survey, the database showed that there were 85 articles by authors from Brazil and 5 articles by authors from "Brasil". In other words, there are actually 90 articles with authors from Brazil. It appears that the Web of Science database was unable to identify that "Brasil" is the spelling of Brazil in Portuguese. There is also an observation regarding the Scopus base. The observation is that the database was not able to identify the country of the authors of 41 articles. This number occupies the second position in the ranking of publications by country, that is, it is only behind Brazil, which has the largest number of published articles. This shows that this inconsistency is significant.

Regarding the subject area, Figs. 3 and 12 show that the area that most published articles was Engineering, followed by the Materials Science and Environmental areas. This on both bases. This result was already expected since the study on aggregates for concrete is strictly linked to Civil Engineering and Materials Science. The fact that the environmental area is the third area with the most publications was also expected. Among the reasons for this result, this present work highlights the fact that efficient use of natural resources is the main global political, social and economic agenda (Fargnoli et al., 2014). As a result, consumers are demanding that companies, such as the Civil Construction Company, which is largely responsible for extracting resources from nature (Mefteh et al., 2013), adopt sustainable processes to produce their products (Adeyeye et al., 2017), forcing it to invest in research in this area.

Another important factor that justifies the positions of the engineering and environmental areas is the increased concern with the destination of waste from the construction industry itself, as this type of waste occupies a lot of space in landfills worldwide (Tam et al., 2018). This factor, together with the fact that the construction industry is a major consumer of natural resources, makes concerns about sustainability occupy more space in this industry (Saieg et al., 2018). The result of these concerns is the production of more research involving the engineering and environmental areas. These researches are mainly focused on replacing natural aggregates with recycled ones, since raw materials, such as aggregates used in concrete, are finite (Onuaguluchi & Panesar, 2014).

As it is a type of waste that occupies a lot of space in landfills around the world, a large number of studies have been identified suggesting the use of waste from the civil construction industry itself (Tam et al., 2016). An example of this type of study is the one carried out in Turkey, where (Elçi, 2016) investigated the use of tile waste as aggregates in the production of concrete, with the objective of reducing the cost of production and minimizing the environmental impact caused by waste from tiles.

Another type of waste that is being investigated as a substitute for some of the natural aggregates in the production of concrete is agricultural waste. Although research on the use of agricultural waste as a concrete aggregate is relatively new (Shafiqh et al., 2014), some studies have been identified in this regard. In their work (Alengaram et al., 2013) they identified 74 studies, only in relation to the use of palm oil as a substitute for part of natural aggregates in the production of concrete. Studies have also been identified that suggest the use of other types of agricultural waste as substitutes for natural aggregates. Residues such as sugar cane ash (Ismail & Jaeel, 2014) and sugar cane bagasse (Sampaio et al., 2014). Several other studies were also identified indicating the feasibility of using, with acceptable performance, various solid agricultural residues, such as coconut husks, rice husks and tobacco residues as aggregates in the manufacture of concrete (Shafiqh et al., 2014).

This work also identified several studies, such as the one carried out which suggest the use of waste tires as part of natural aggregates in the production of concrete.

In addition to the residues, this work identified several other studies suggesting other types of residues as a substitute for natural aggregates in the production of concrete. Among them, the polyethylene terephthalate residue (Frigione, 2010) (Saikia & De Brito, 2013). Or yet, proposals such as the use of ash from incinerated waste in dumps (Wegen et al., 2013) (Abbà et al., 2014), steel slag (Netinger et al., 2011), iron ore tailings (Shettima et al., 2016) and sewage sludge (Kosior-Kazberuk, 2011).

The analysis of the data referring to articles in the environmental areas are remarkably like the analysis made referring to the data of the total articles in the two databases. The first article, on the Scopus database, was published in 1976 and on the Web of Science database in 1992. The trend, in both bases, is for growth starting in 2006, the same trend seen in both bases when analyzing articles from all areas. The relevant differences in relation to the evolution of the number of publications were found in the Scopus database. The first difference is that the peak in the number of publications was in 2018, as opposed to the peak of publications on articles from all areas, which was in 2019. The second difference

is that there was a decrease in the number of publications of articles in the environmental area in 2019, while the number of publications for articles in all areas increased. The third difference is that Brazil becomes the second country to publish articles with the characteristics studied in this present work. India is in now first place. The fourth and final difference is the inclusion of the Single Kingdom among the main countries that have published articles.

## **4.2 Considerations about articles with Brazilian authors**

Among the main information, in relation to articles with Brazilian authors, the fact that Brazil is in first place in number of publications in both bases stands out. The evolution of the number of articles with published Brazilian authors is similar in both bases. Upward trend with peak in the number of publications in 2019.

Following the global trend, the largest number of Brazilian articles is from the Engineering area, followed by the Materials Science area, in both bases. In third place comes the Construction Building Technology area, on the Web of Science base, and Physics and Astronomy on the Scopus base. The environmental area is in the fourth position, in the Web of Sciences base, and in the fifth position, in the Scopus base. It is worth mentioning that the Engineering, Construction Building Technology and Materials Science areas are related to civil engineering. In this way it is possible to affirm that a large part of the Brazilian articles identified here are from the area of Civil Engineering. The fact that the majority of articles by Brazilian authors are from the engineering area may have as one of the reasons that the construction industry has a great weight in the Brazilian economy (William et al., 2013). In 2014, the construction industry was responsible for 14% of the Gross Domestic Product (GDP) in Brazil. This industry also has great social importance, since it generates a large part of jobs for the most disadvantaged population (Santana & Oliveira, 2004).

Despite the articles in the environmental area occupying the fourth (Web of Sciences base) and the fifth (Scopus base) place in the ranking of research areas, when considering only articles with Brazilian authors, these articles occupy a prominent position, globally. In the Web of Science base, it is in first place and in Scopus in second. You also must consider that the keywords investigated here are very much related to engineering. So, it is natural to obtain more articles related to engineering, which was the case.

The fact that the environmental area appears right after the engineering areas is a strong indication that the environmental issue is a truly relevant topic for Brazil. However, considering the relevant environmental issue does not mean having an optimal condition in relation to the environment. Although Brazil publishes a lot about the environmental area, the country has difficulty in dealing with sustainability. Among the main reasons for this difficulty is Brazil's delay in taking concrete actions to achieve sustainability. An example of this delay are actions to tackle the issue of post-consumer waste, which had as a landmark the National Solid Waste Policy (NSWP) (DEMAJOROVIC & Migliano, 2013). Although the NSWP was regulated on December 23, 2010, it still faces difficulties in its real implementation in relation to the collection, recycling and reverse logistics of various wastes, mainly e-waste (DEMAJOROVIC et al., 2016). The consequence of these delays is the country's difficulty in

correctly managing its waste, such as e-waste, which has an estimated collection rate of only 2% (Azevedo et al., 2017).

## 4.3 Considerations on the data in Chart 1

The first information that this work highlights from Chart 1 is that most studies used the experimental research methodology, with 31 articles, representing more than 88% of the articles. The rest of the articles used the case study methodology, two of which analyzed the product life cycle.

This present work used the tools of the Scopus and Web of Science databases to identify articles that have the words concrete, aggregate and residue in their title or abstract or Keywords. However, these tools returned articles that did not meet the research parameters, as can be seen in Figs. 21, 22 and 23. When analyzing the information of the articles, provided by the tools of the databases, in relation to the title of the articles (Fig. 21), it is possible to verify that only two articles met the research parameters. Regarding the information about the abstract (Fig. 22), only 14 articles. And lastly, regarding the Keywords (Fig. 23), no article was identified. It is important to note that in five articles all three words investigated by this work appeared in two items, that is, in the title or in the abstract, in the title or in the Keywords or in the abstract and Keywords. Thus, of the 35 articles provided by the database tools, only 11 fully met the research parameters.

When considering the word “waste”, which is a synonym for residue, the number of articles that met the search parameters are 4, 18 and 1 for the titles, abstract and keywords respectively. Subtracting the five articles that contain the words in more than one item, gives a total of 18 articles. Thus, even validating the word “waste”, almost 50% of the articles provided by the databases did not meet the research parameters.

It is worth highlighting the information shown in Fig. 24, where it shows that the waste that is most studied, by the selected articles, is the waste of the civil construction industry itself. This fact shows that Brazilian research follows the global trend, since the waste from the construction industry is the most investigated to be used as a substitute for raw material in this industry. Another important highlight that can be observed in the data in Fig. 24 is in relation to agricultural waste. There are several types of agricultural waste being investigated in these articles. Thus, if agricultural waste is grouped into a single type of waste, it would occupy the first position, with seven articles.

## 5 Conclusions

The words aggregate, residues and concrete are strongly related to the area of Engineering, mainly Civil Engineering. They are also strongly related to environmental areas. This confirms the hypothesis that using these words, in the search for articles on substitution of natural aggregates for recycled ones, is an efficient way to start a research on the subject. This search will return many articles dealing with engineering and environmental issues.

The result of the search in the articles, from the Environmental area of Brazilian authors, showed that the word “waste” had a higher frequency than the word “residue”. Thus, this work evaluates that it is important to include the word “waste” as a parameter in research when the objective is to investigate the replacement of natural aggregate by waste in the production of material for the civil engineering industry.

The positive evolution of the number of publications with the words aggregates, residues and concrete in the title, or in the summary or in the key words, shows the commitment of organizations to sustainability. This evolution occurs both in articles in the engineering and environmental areas, as well as in the sum of articles in all areas.

Brazil is the country with the largest number of articles published in the Scopus and Web of Sciences databases when considering all areas. It is also the first in the environmental field at the Web of Sciences database. At the Scopus base, it is in second place. These positions in Brazil show the country's commitment to sustainability. However, Brazil still faces great challenges to achieve it, mainly in relation to waste management.

This work suggests that the Web of Science and Scopus databases analyze the possibility of reviewing the data available in their article databases. It also suggests a review of the grassroots research tools. The reasons for these suggestions are that an inconsistency in the number of articles with Brazilian authors was identified in the Web of Science database and a large number of articles without identifying the nationality of the authors in the Scopus database. In addition to these inconsistencies in the databases, it was identified that the search engines returned articles that did not fully meet the research requirements.

The research result, showing that the word "waste" occurred more than the word "residue", suggests that it is important to include the word "waste" as a search parameter. What will be done in a future work to compare with this one.

## **Declarations**

### **Acknowledgment**

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- Federal University of Itajubá – UNIFEI

### **Ethics approval and consent to participate**

Not applicable.

### **Consent for publication**

Not applicable.

## Availability of data and materials

All data generated or analysed during this study are included in this published article.

## Competing interests

The authors declare that they have no competing interests.

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## Authors' contributions

JHFG, VCS and CHPM defined the theme, suggested the research bases and guided the review process. CAA performed the searches in the databases, produced the graphics with the data obtained in the articles, performed the analysis on the data and issued the conclusions.

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## Figures

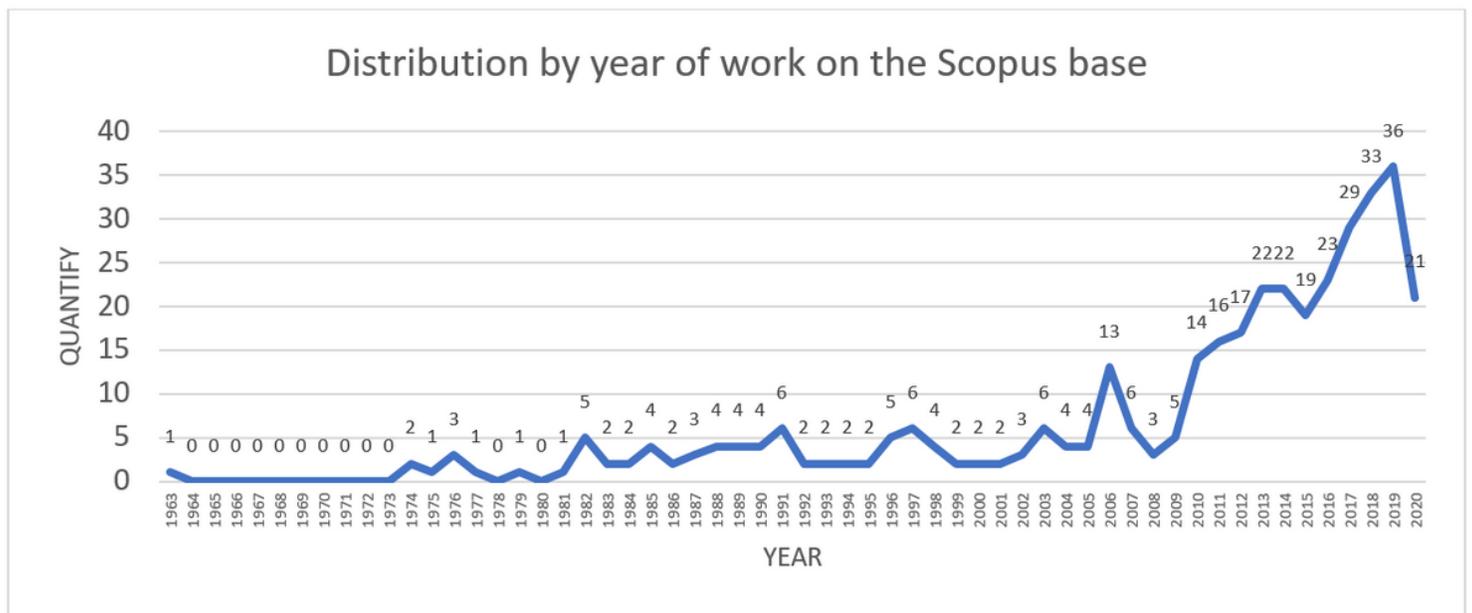
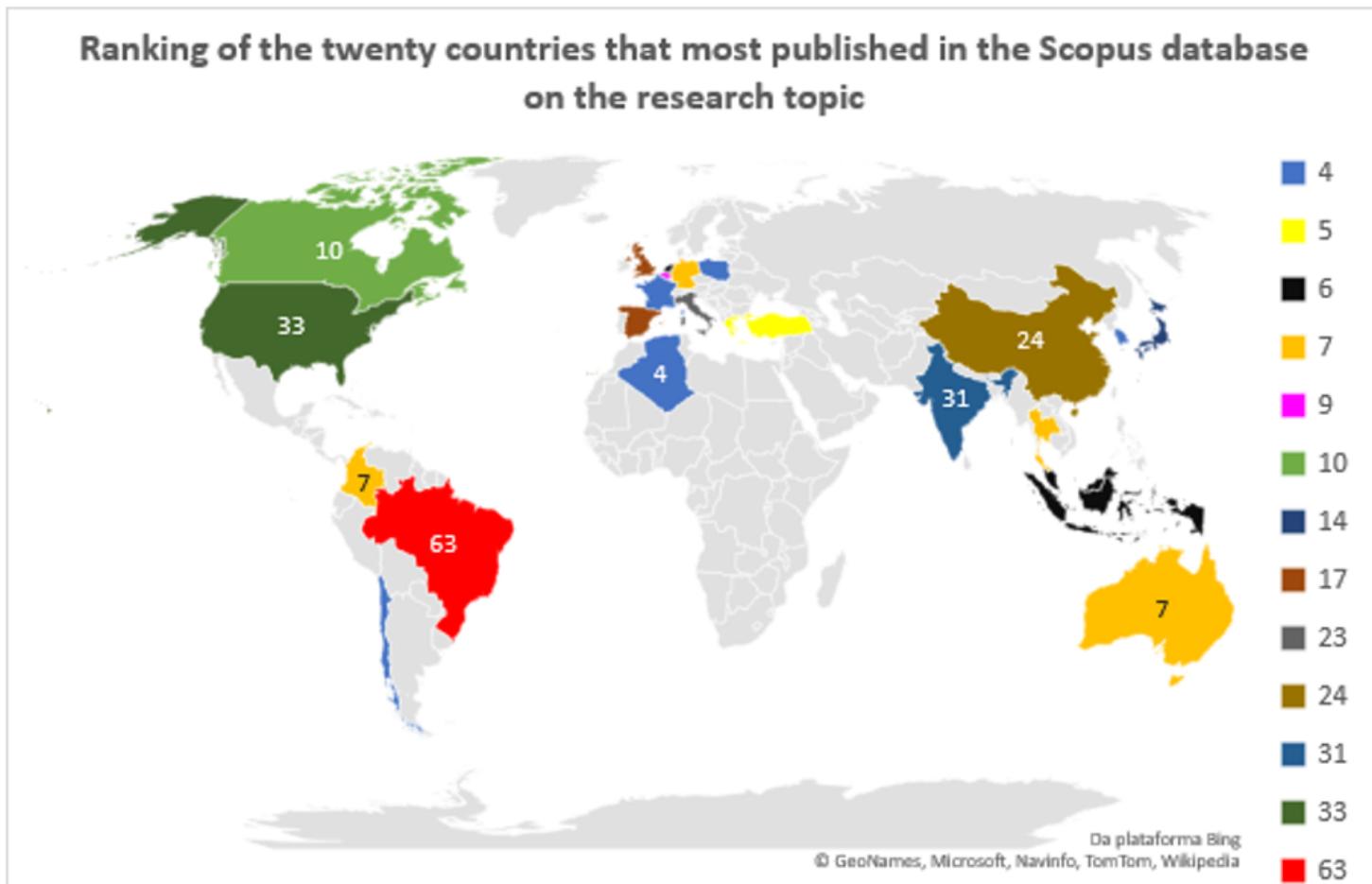


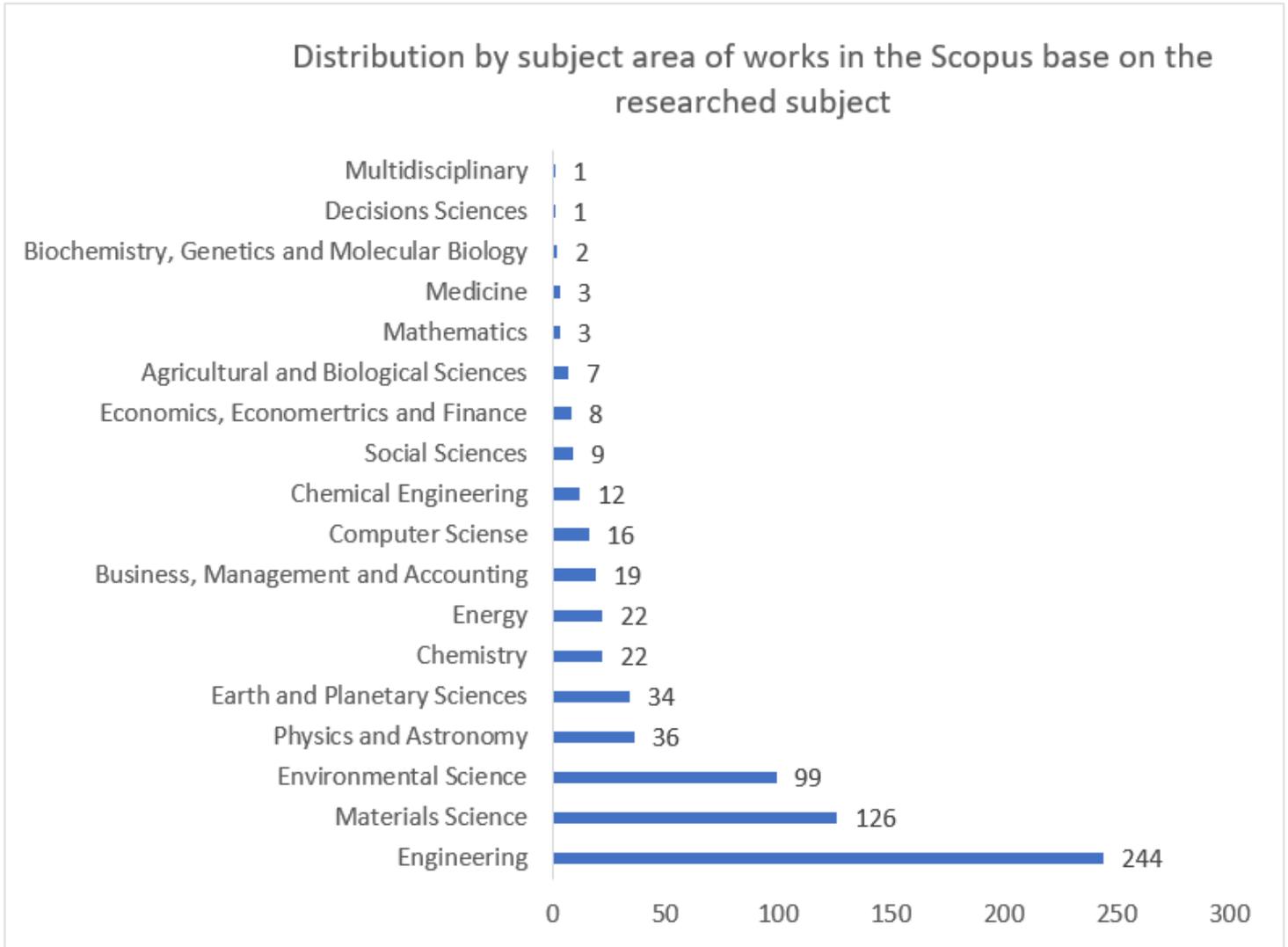
Figure 1

Distribution, by year of publication, of the articles researched in the Scopus database.



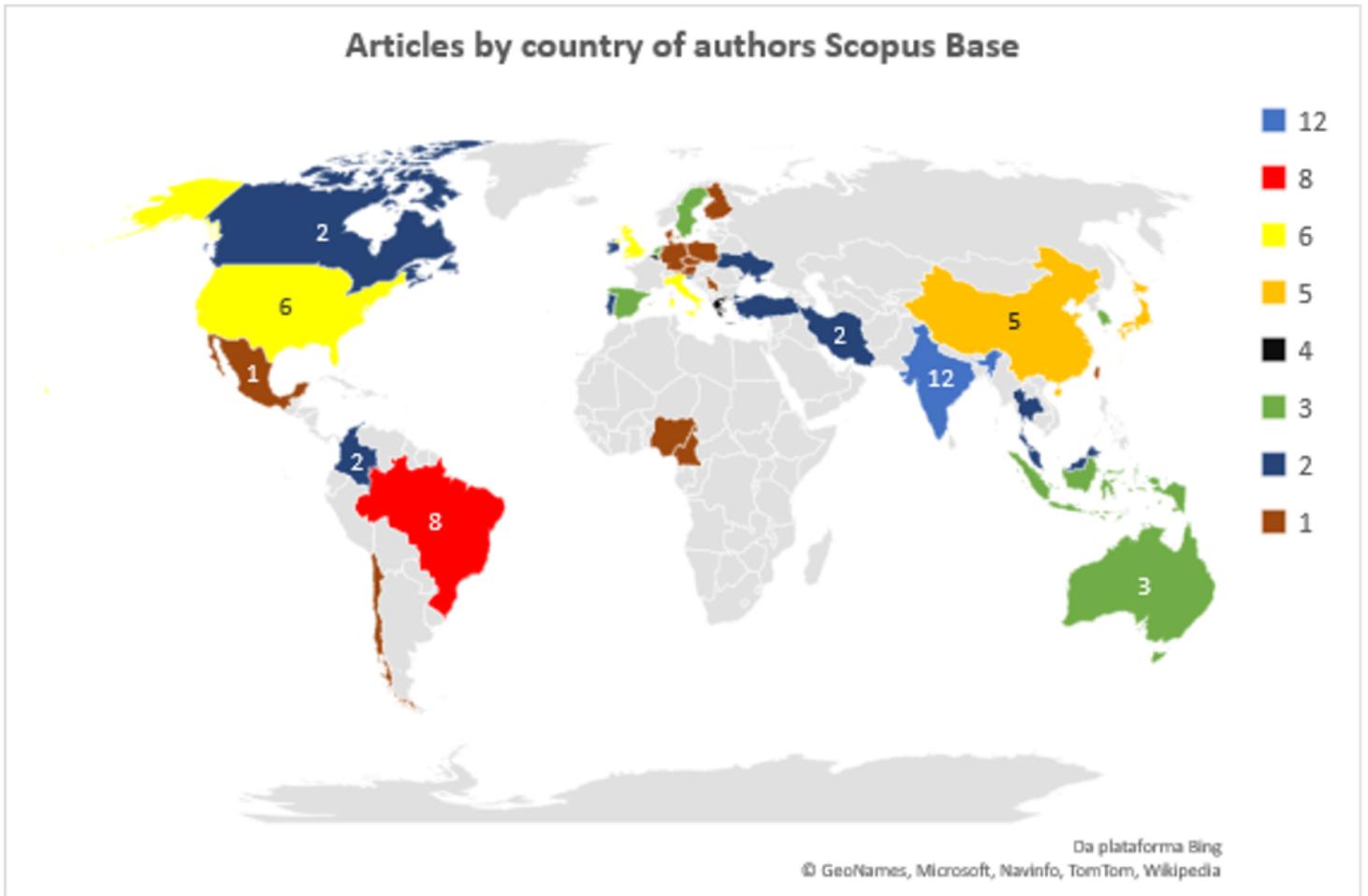
**Figure 2**

The 20 countries that most published articles with the words aggregates, residues, concrete in the title or keywords or in the abstract. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.



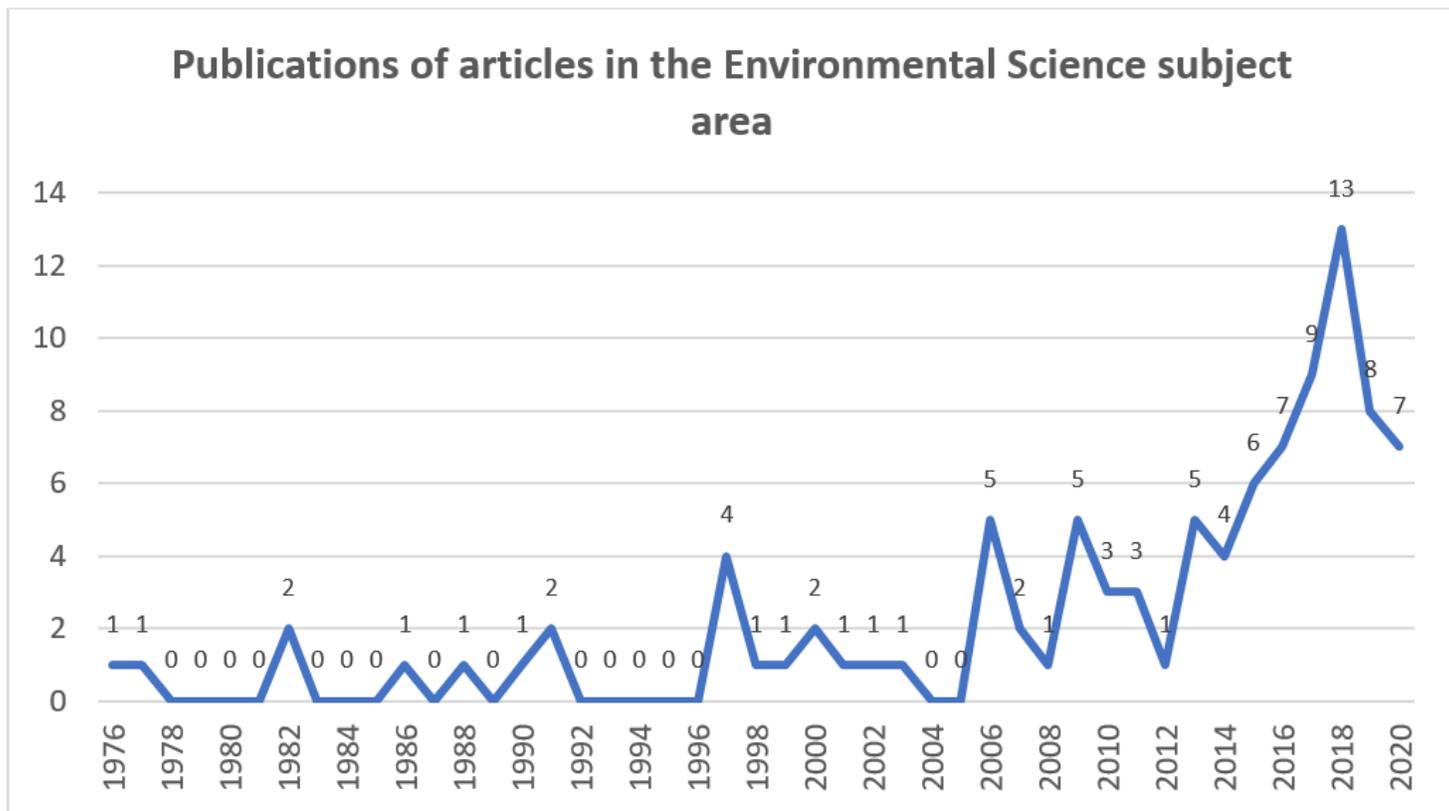
**Figure 3**

Articles found in the Scopus database by subject area



**Figure 4**

Distribution, by country, of the 99 articles in the Environmental Science subject area, containing the words aggregates, residues and concrete in the title or in the keywords or in the abstract. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.



**Figure 5**

Evolution of the number of publications of articles in the Environmental Science subject area in the base Scopus

## Main information in the Scopus database

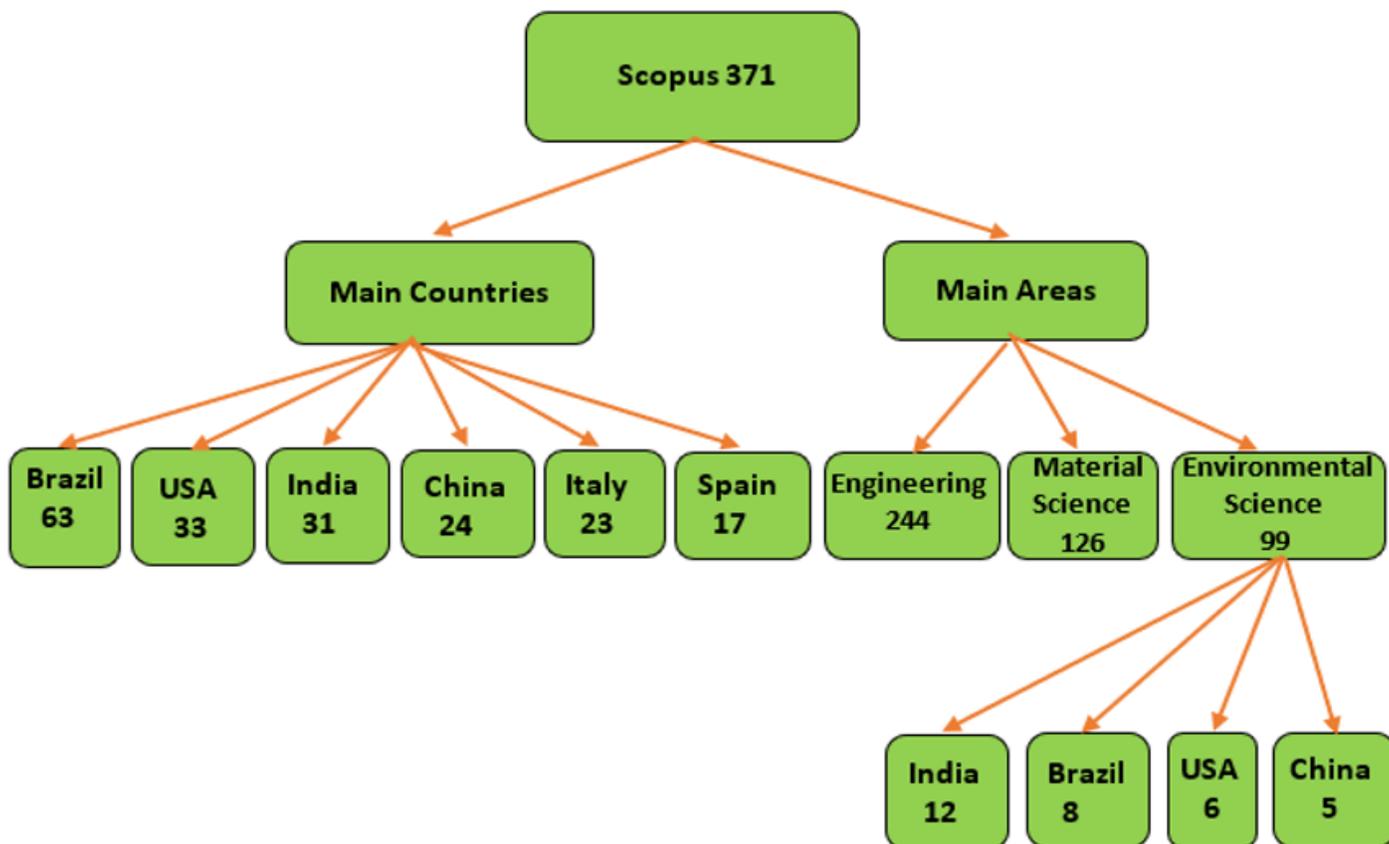


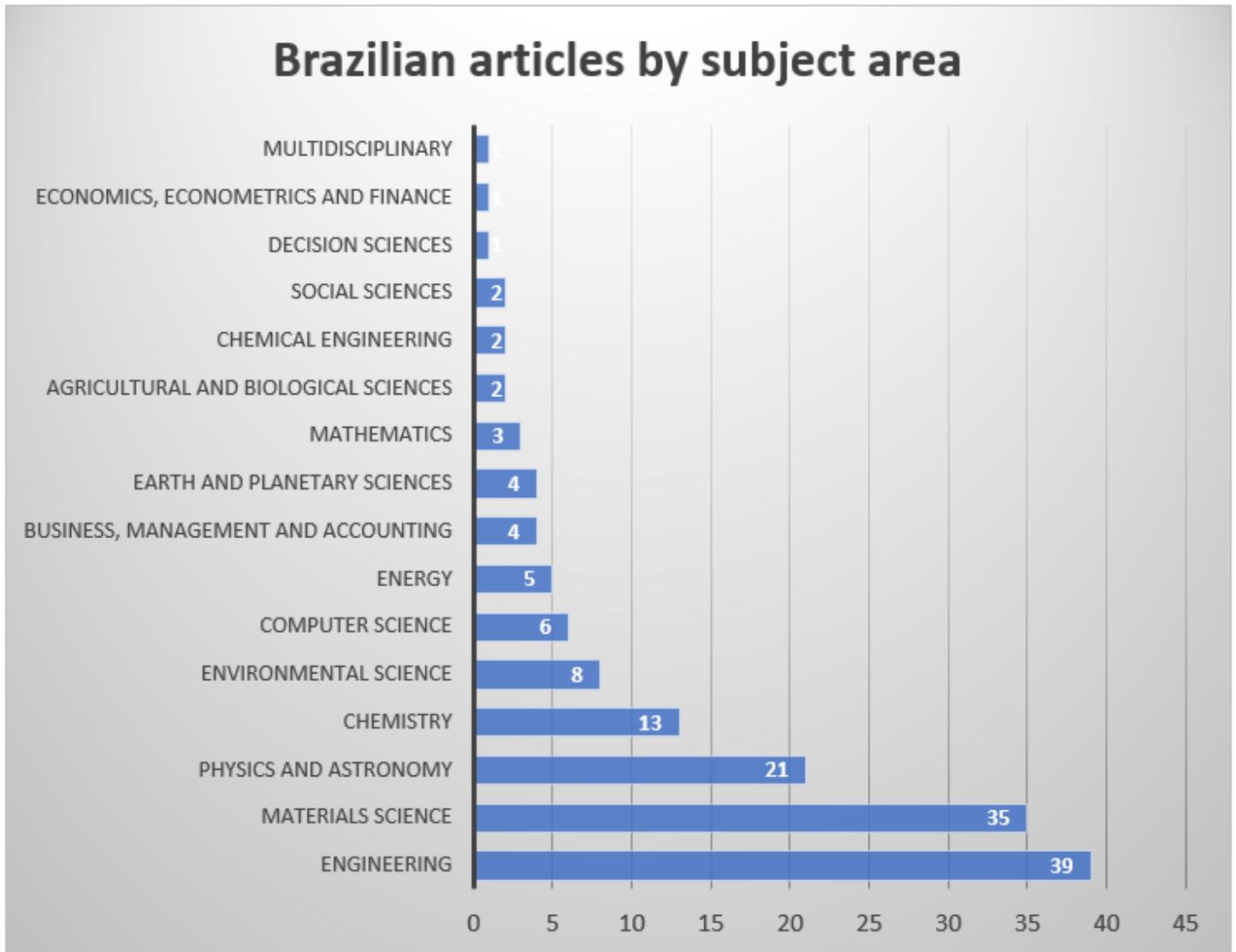
Figure 6

Summary of the main information obtained in the Scopus base of articles with the words aggregates, residues and concrete in the title, abstract or keywords



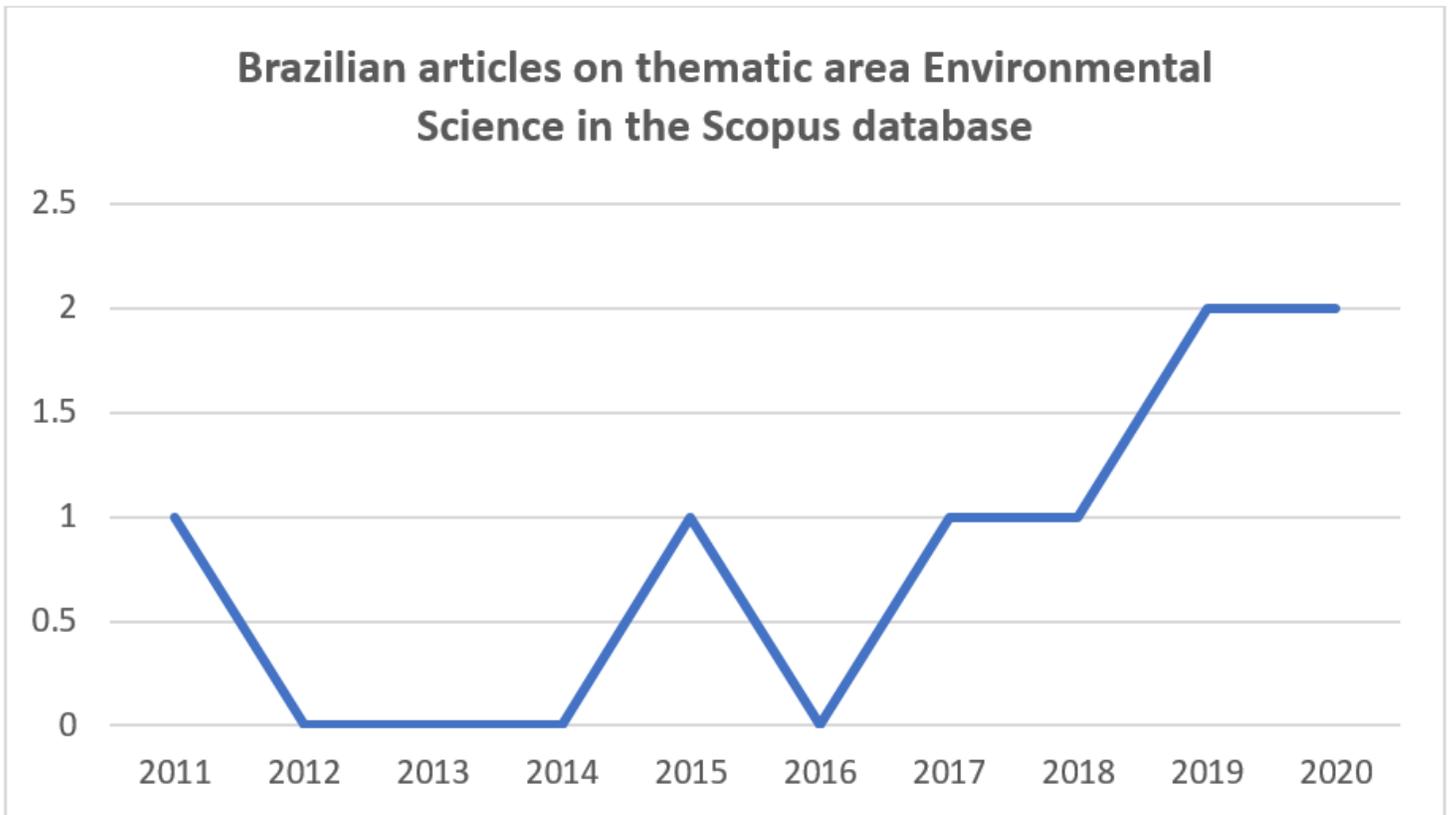
Figure 7

Evolution of the number of Brazilian publications of articles with the words aggregates, residues and concrete in the title or in the keywords or in the abstract



**Figure 8**

Distribution, by subject area, of Brazilian articles containing the words aggregates, residues and concrete in the title or in the keywords or in the abstract, in the base Scopus



**Figure 9**

Yearly distribution of Brazilian articles on thematic area Environmental Science in the Scopus database

# Main information of articles with Brazilian authors in the Scopus database

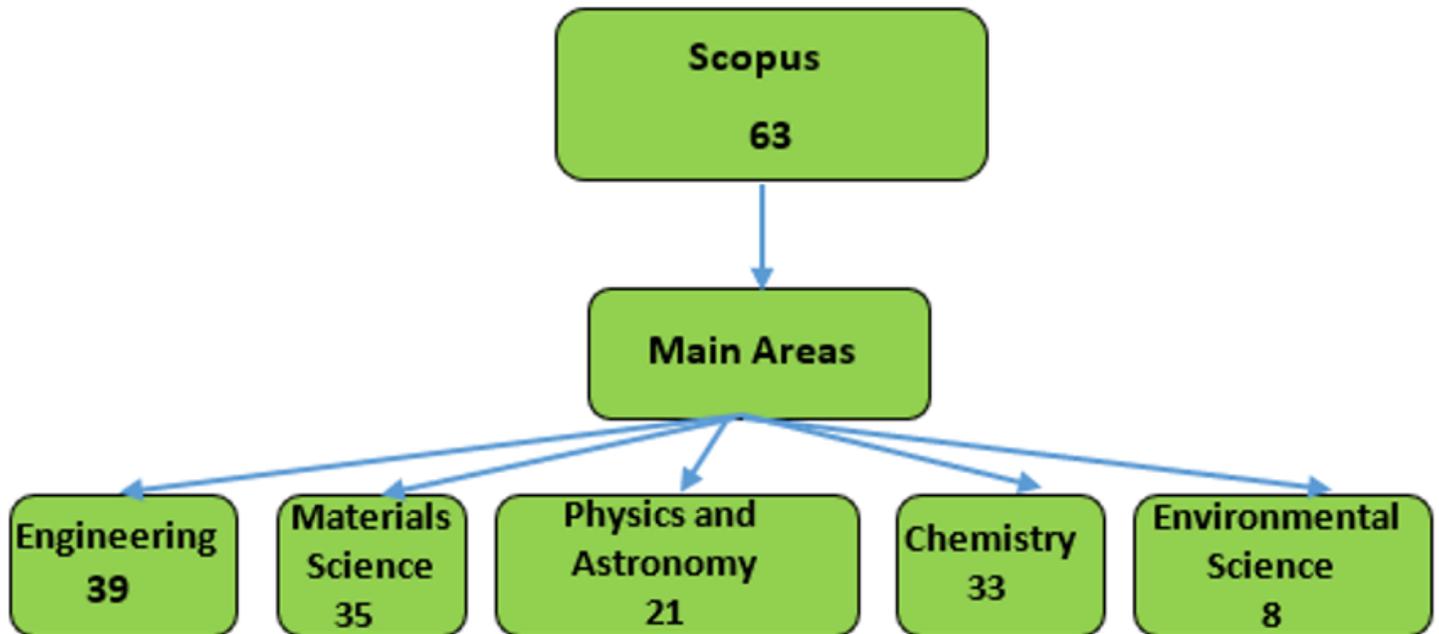


Figure 10

Summary of the main information obtained in the Scopus base of articles with Brazilian authors with the words aggregates, residues and concrete in the title, abstract or keywords

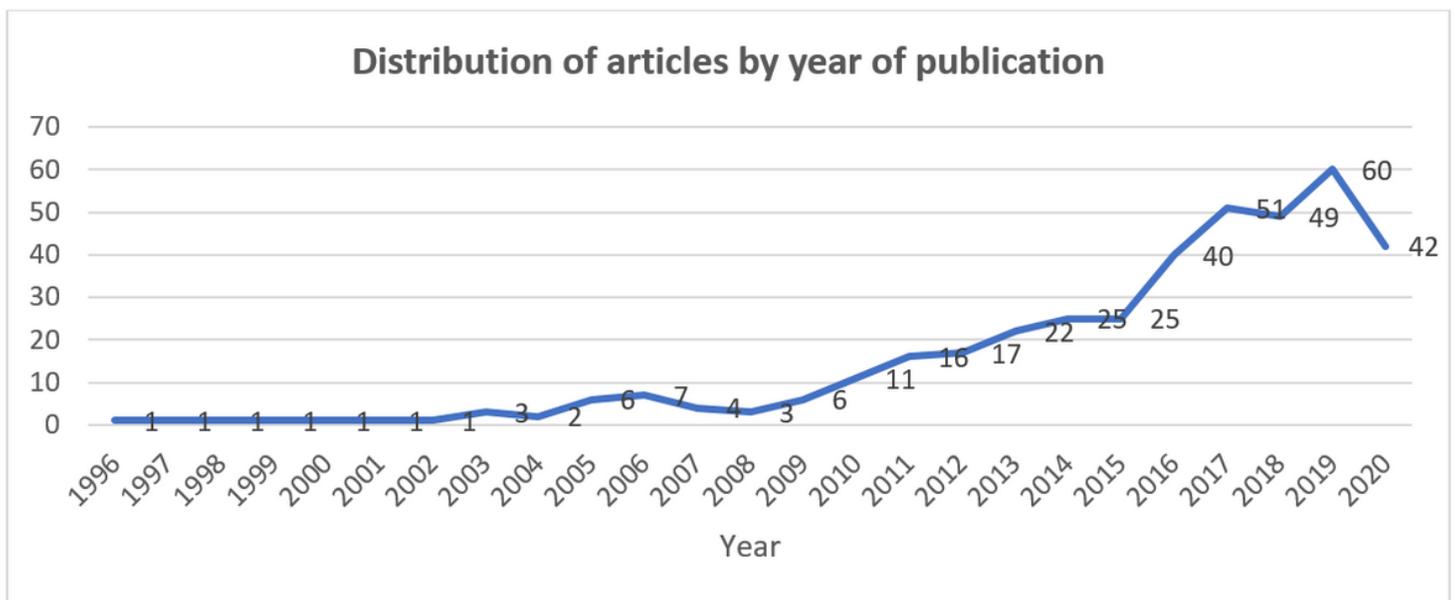
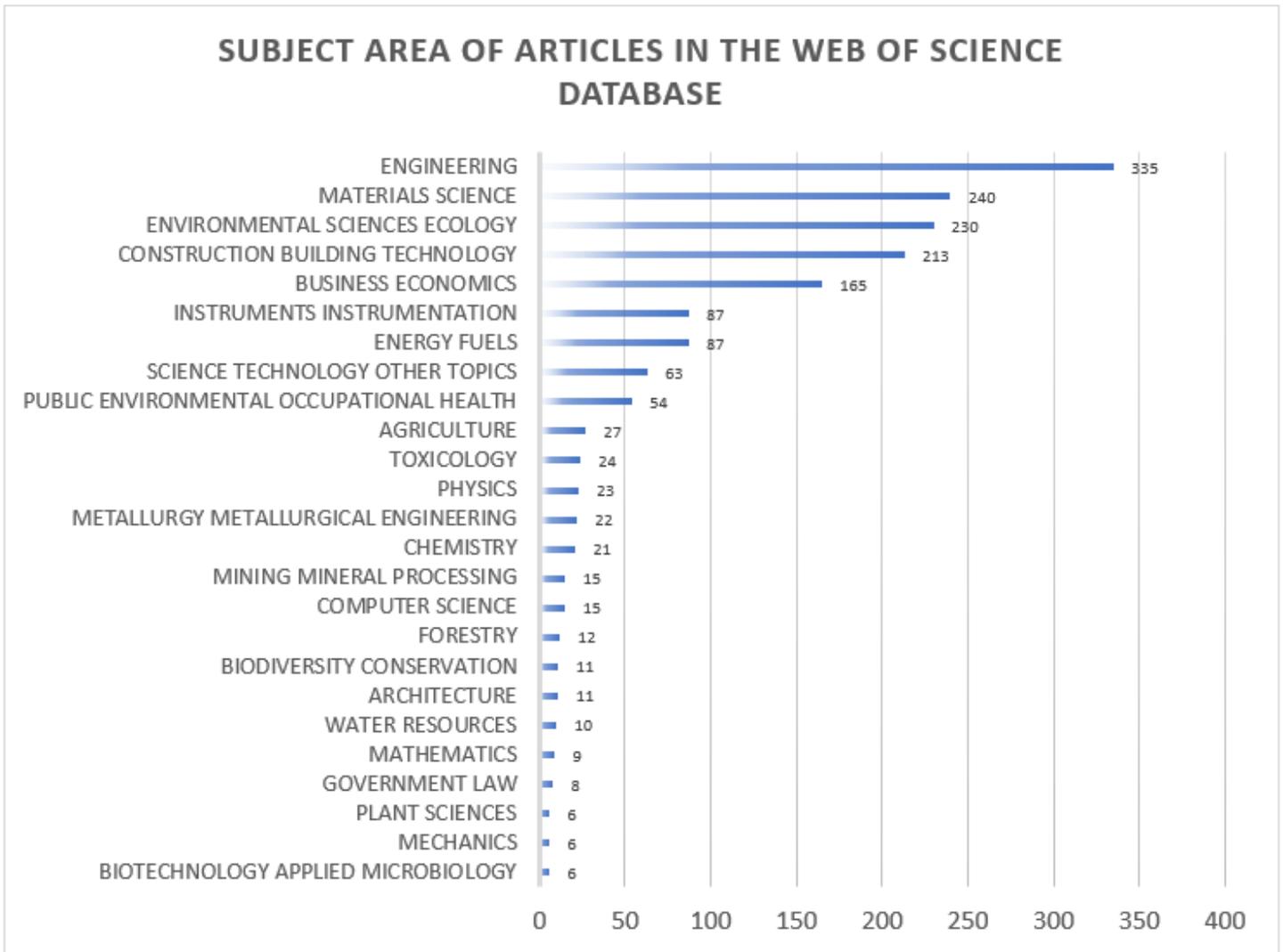


Figure 11

Articles with the words aggregates, residues and concrete in the title or keywords or abstract of the Web of Sciences database



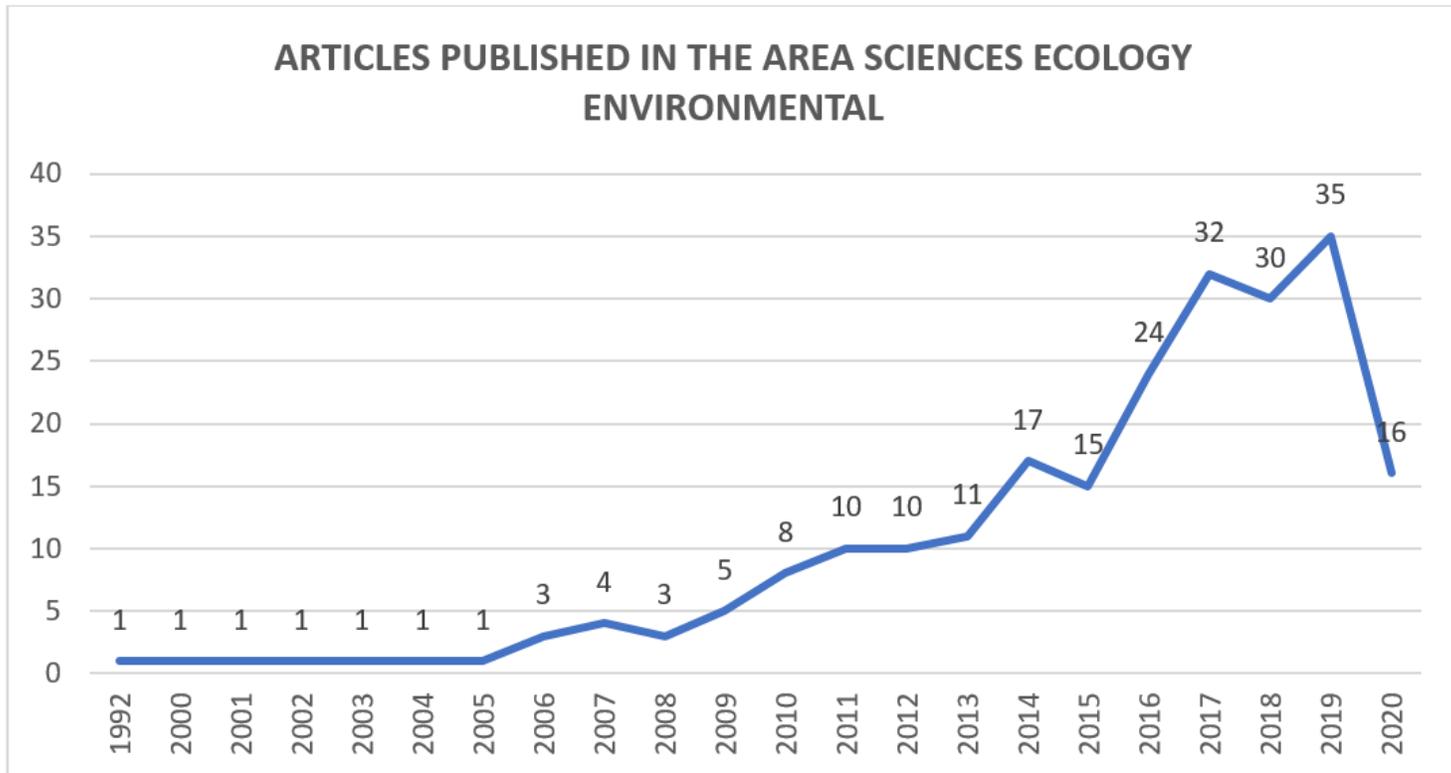
**Figure 12**

Distribution, by subject area, of articles with the words aggregates, residues and concrete in the title or keywords of the Web of Sciences database



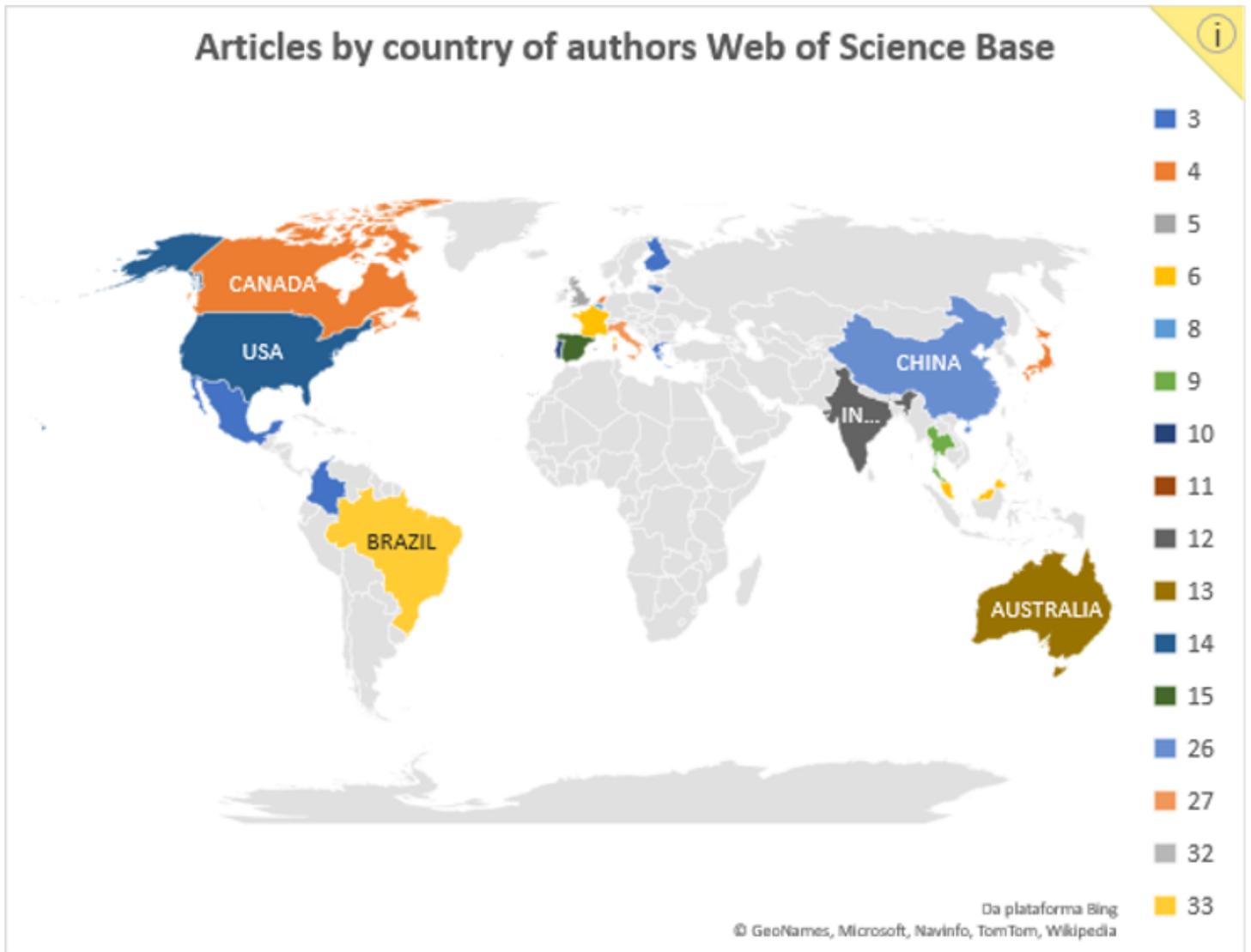
**Figure 13**

Distribution, by country, of the 401 articles containing the words aggregates, residues and concrete in the title or in the keywords or in the abstract. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.



**Figure 14**

Distribution, by year of publication, of articles in the Sciences Ecology Environmental area, on the Web of Science database



**Figure 15**

The 230 articles in the subject area Environmental Sciences Ecology, containing the words aggregates, residues and concrete in the title or in the keywords or in the abstract in the Web of Sciences base. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

## Main information in the Web of Sciences database

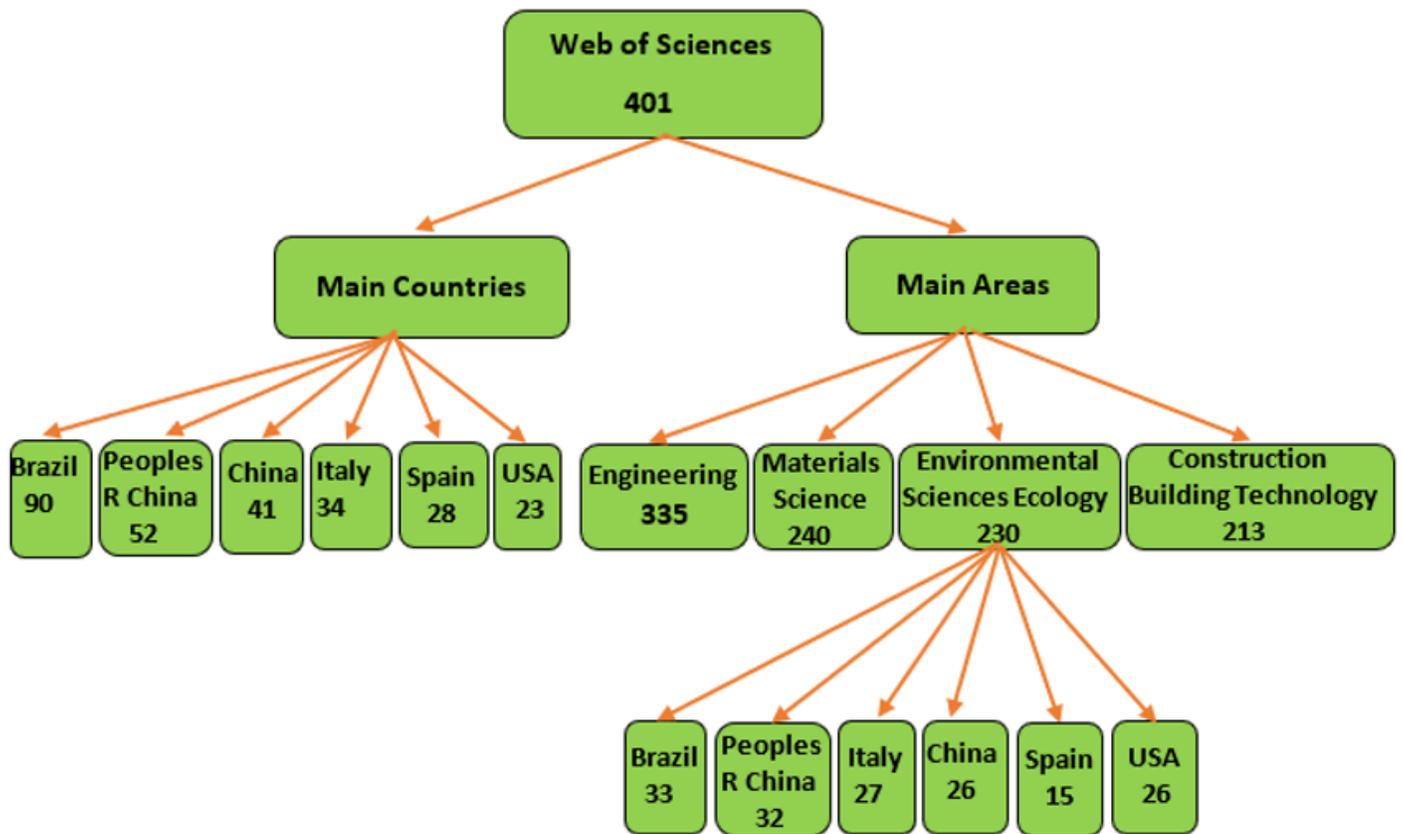


Figure 16

Summary of the main information obtained in the Web of Sciences base of articles with the words aggregates, residues and concrete in the title, abstract or keywords

## Subject area of articles in the Web of Sciences database of the Brazilian articles

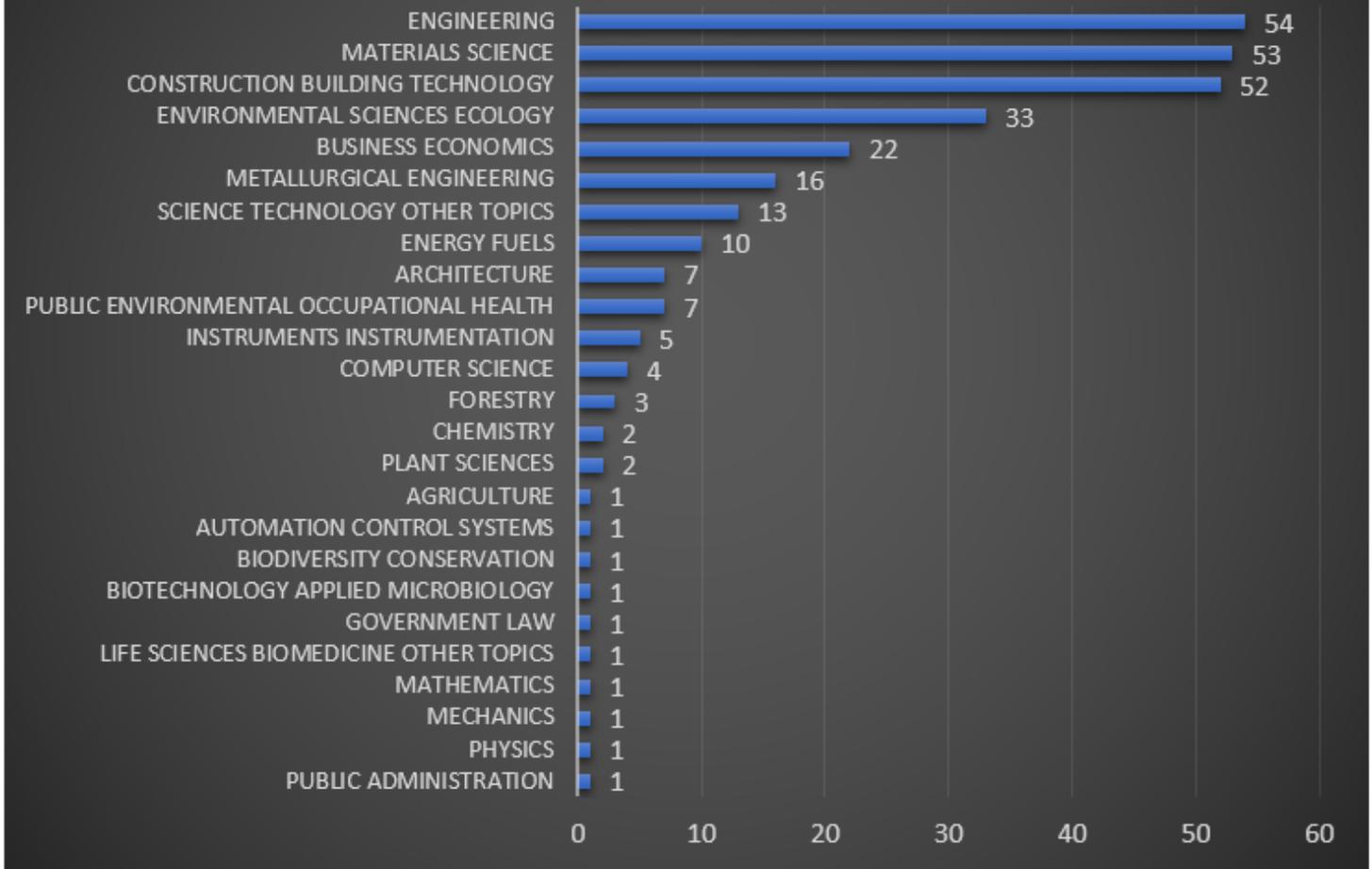
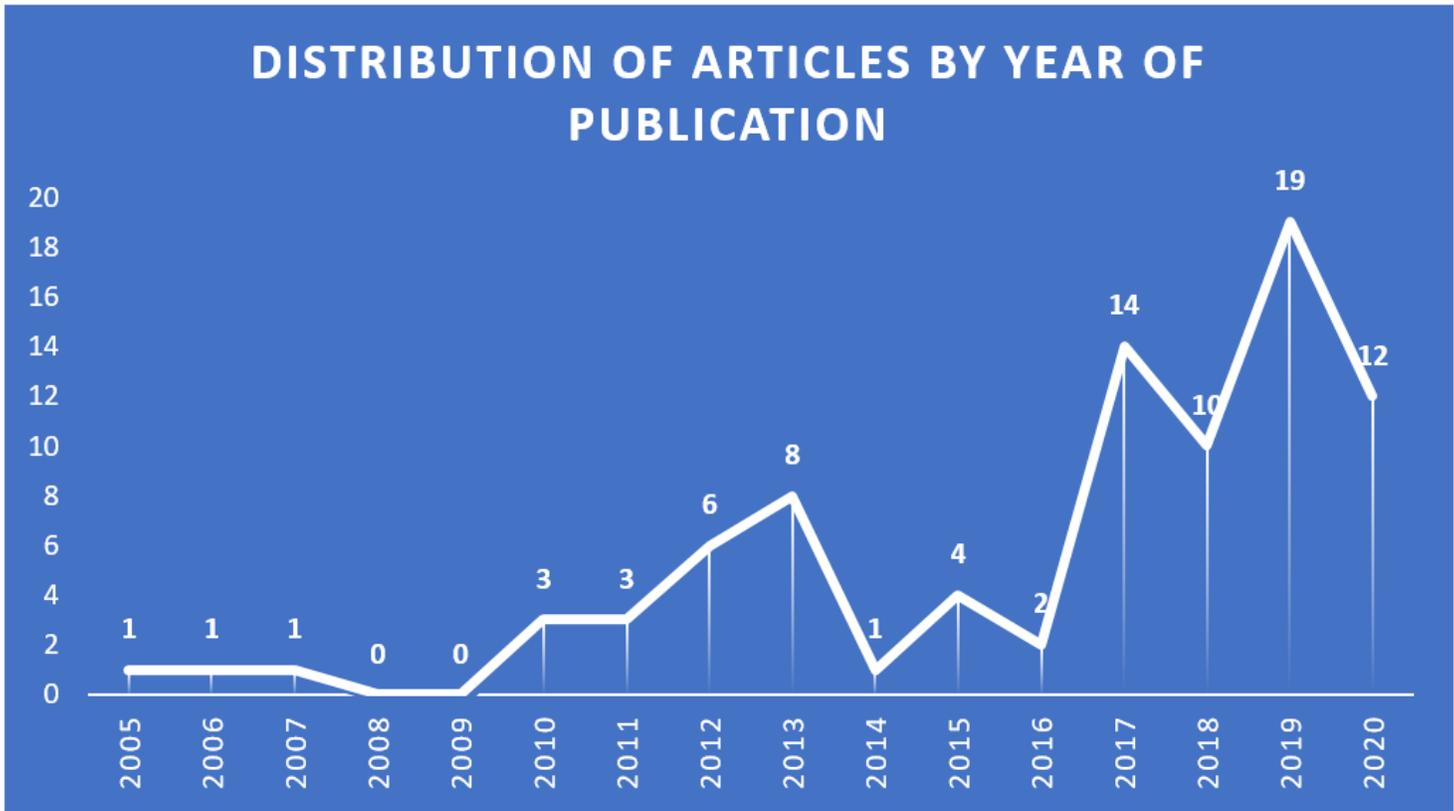


Figure 17

Distribution, by subject area, of the Brazilian articles in the Web of Sciences database.



**Figure 18**

Distribution, by year of publication, of the articles by Brazilian authors, on the Web of Sciences database.

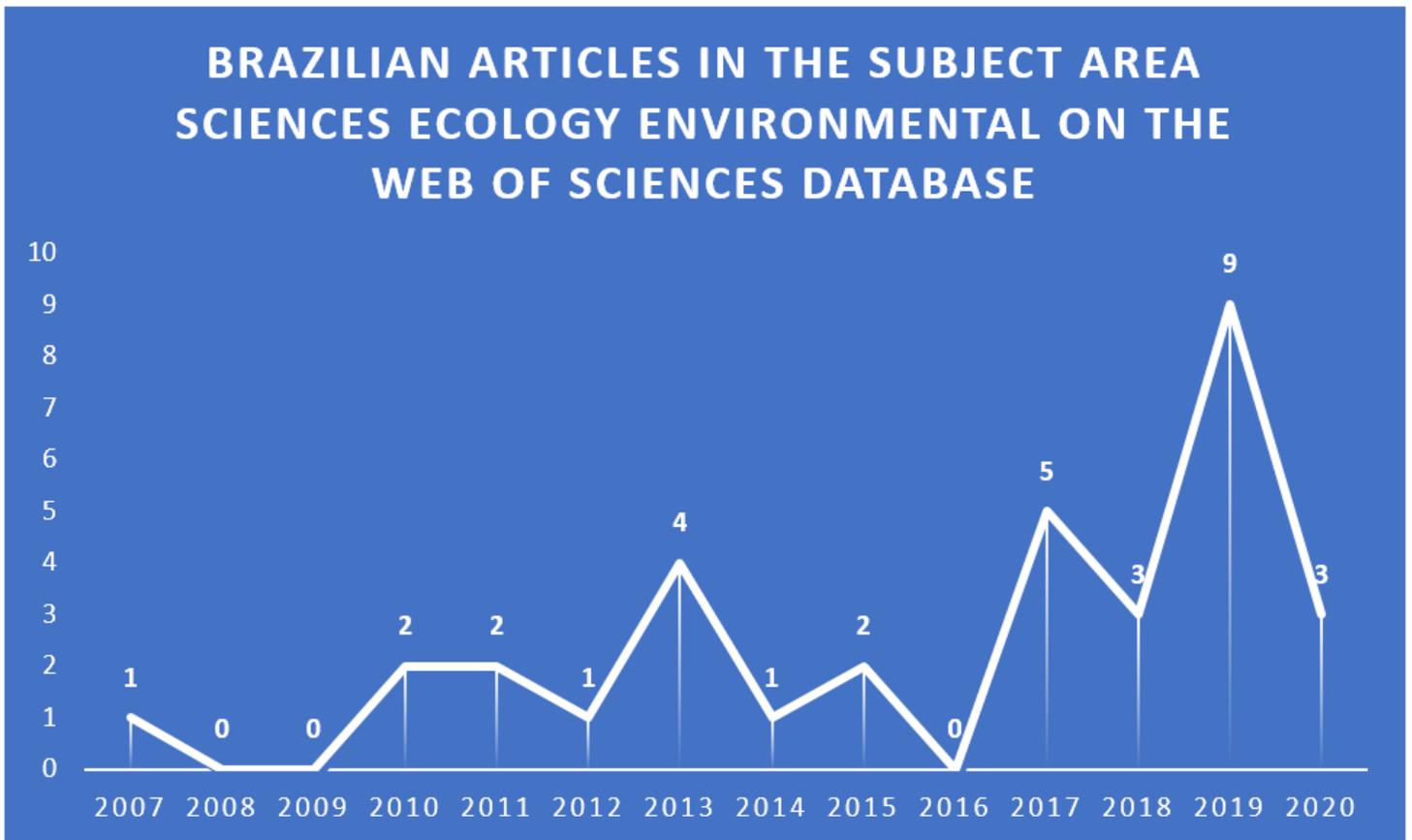


Figure 19

Distribution, by year of publication, brazilian articles in the subject area Sciences Ecology Environmental on the Web of Sciences database

## Main information of articles with Brazilian authors in the Web of Sciences database

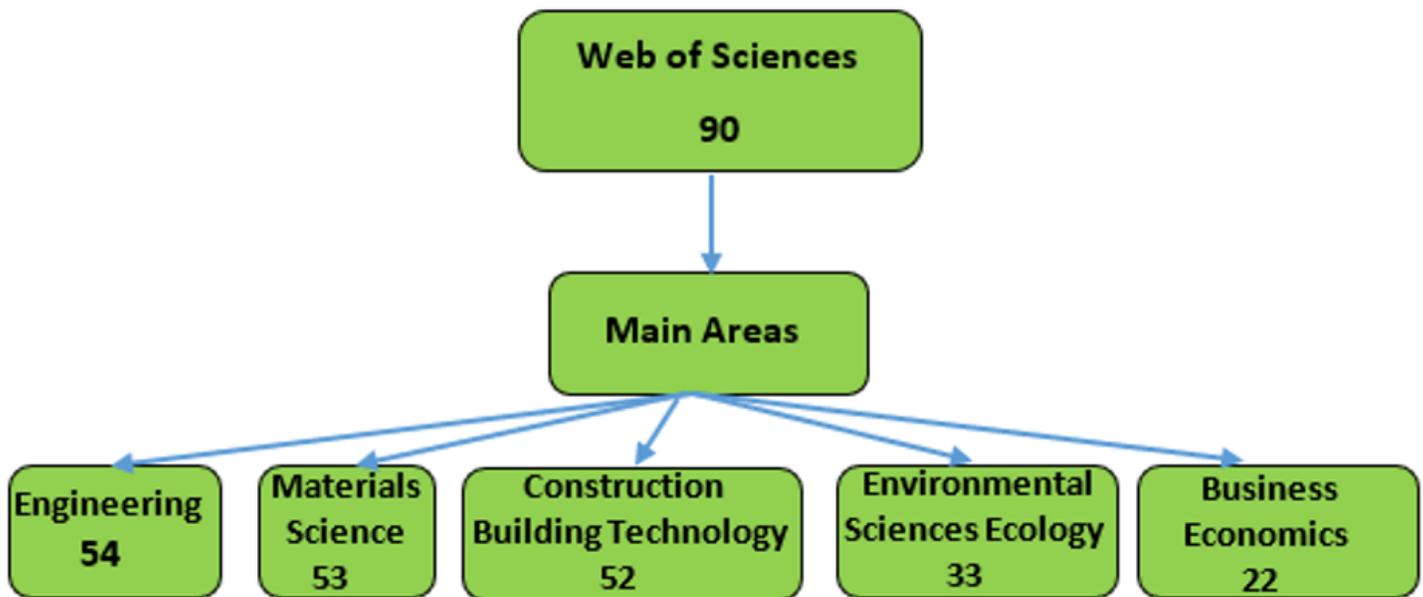


Figure 20

Summary of the main information obtained in the Web of Sciences base of articles with Brazilian authors with the words aggregates, residues and concrete in the title, abstract or keywords