ISSN 0798 1015

REVISTA ESPACIOS

HOME Revista ESPACIOS ÍNDICES A LOS AUTORES

Vol. 38 (Nº 29) Año 2017. Pág. 22

Análise e perspectivas de alternativas para destinação de resíduos de rochas ornamentais através de um estudo bibliométrico

Analysis and perspectives of alternatives for the destination of ornamental stone residues through a bibliometric study

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Recibido:13/01/2017 • Aprobado: 18/02/2017

Conteúdo

RESUMO:
Este trabalho traz uma análise e perspectivas de alternativas para destinação de resíduos de rochas ornamentais através de um estudo bibliométrico. O estudo foi realizado em dezembro de 2016 e considerou artigos publicados nos últimos cinco anos na plataforma ScienceDirect (Elsevier). Os artigos foram classificados por áreas de reaproveitamento do resíduo, periódico, ano e região geográfica. Constatou-se que há tendência crescente no número de publicações e a maior área de reaproveitamento é a construção civil.
Palavras chave: Resíduos de rochas ornamentais, reaproveitamento, estudo bibliométrico.

ABSTRACT:
This paper presents an analysis and perspectives of alternatives for the destination of ornamental stone residues through a bibliometric study. The study was conducted in December 2016 and considered articles published in the last five years on the platform ScienceDirect (Elsevier). Articles were classified by areas of reuse of the waste, periodical, year and geographic region. It was observed that there is an increasing trend in the number of publications and the largest reuse area is civil construction.
Key words: Ornamental stone residues, reuse, bibliometric study

1. Introdução

As rochas ornamentais são materiais rochosos extraídos e beneficiados com finalidade de uso estrutural, de revestimento ou de decoração. Comercialmente, as rochas ornamentais são divididas principalmente em mármores e granitos (Cetem, 2013). Essas rochas são

reconhecidas pela qualidade, durabilidade, variedade e beleza o que explica seu uso na maioria dos projetos arquitetônicos mundiais.

No Brasil a indústria de rochas ornamentais é expressiva. Em 2014, o país foi o quarto maior produtor mundial e o quinto maior exportador. O estado do Espírito Santo lidera o ranking nacional como maior produtor, tanto na lavra quanto no beneficiamento, e também como maior exportador (Montani, 2015). Em 2015, a produção brasileira de rochas ornamentais foi de cerca de 9,5 milhões de toneladas, aproximadamente 7% da produção mundial. As rochas ornamentais foram o quinto maior produto de base mineral exportado pelo Brasil, totalizando 2,32 milhões de toneladas, que corresponde a US$ 1,21 bilhão e gerando US$ 1,17 bilhão de saldo positivo na balança comercial brasileira (Abirochas, 2015).

Porém, essa indústria também gera degradação de áreas naturais no processo de lavra das rochas e grande quantidade de resíduos sólidos no processo de beneficiamento (Cetem, 2013). Baseado em dados da Abirochas (2015) estima-se que foram gerados cerca de 2,5 milhões de toneladas somente de resíduos finos e ultrafinos, como efluentes, em forma de lama no Brasil no ano de 2015. Esses efluentes ficam armazenados nas serrarias em lagoas abertas e são um problema para os empresários que não conseguem uma melhor destinação aos Resíduos de Rochas Ornamentais (RRO).

Temas ambientais, como os RRO têm tomado cada vez mais importância no cenário mundial devido às alterações climáticas e à poluição que se agravaram após a Revolução Industrial. A Conferência das Nações Unidas sobre o Meio Ambiente e o Desenvolvimento, em 1992, consolidou em nível mundial a necessidade de desenvolvimento sustentável.

Nesse contexto, o artigo destina-se a avaliar a dinâmica e a evolução da informação científica sobre o uso dos RRO com o objetivo de identificar as alternativas de destinação adequada desses resíduos industriais, de forma que sejam reaproveitados ao invés de descartados. Para isso, foi realizada uma análise bibliométrica com termos correlatos ao tema na plataforma *ScienceDirect*, da Elsevier, com auxílio do Portal de Periódicos da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES).

1.1. Resíduos de rochas ornamentais

Neste estudo, os RRO são considerados resíduos finos originários do processo de beneficiamento das rochas ornamentais. Eles podem ter composição à base de silicato se provenientes de granito ou composição à base de carbonato se provenientes de mármore (Chiodi Filho, 2002).

No Brasil, o RRO é classificado de acordo com a norma regulamentadora NBR 10004:2004 como resíduo não perigoso e inerte (ABNT, 2004). Entretanto, os estudos de classificação ambiental de Braga*,* Buzzi, Couto & Lange (2010) e Manhães & Holanda (2008) afirmam que os RRO podem ser classificados como resíduo não perigoso e não inerte. Também o estudo de De Freitas, Raymundo, & De Jesus (2012) classifica os RRO como resíduo perigoso. Assim, esses resíduos podem prejudicar o meio ambiente se não dispostos adequadamente.

Os RRO, além de prejudicarem o meio ambiente, também causam transtorno para os empresários do setor no Brasil devido ao grande volume gerado e aos custos de transporte e aterro dos mesmos.

No processo de beneficiamento, aproximadamente 26% das rochas extraídas se transformam em resíduos finos (2-0,075 mm) e ultrafinos (<0,075 mm) na forma de efluente, que são basicamente uma mistura de pó de rocha, água e insumos de serragem e polimento, do qual aproximadamente 95% da água é recirculada no processo e os sólidos ficam dispostos nos pátios das serrarias e posteriormente são destinados a aterros (Cetem, 2013). Dessa forma, usando como base os dados da Abirochas (2015), estima-se que foram gerados aproximadamente 2,5 milhões de toneladas somente de resíduos finos e ultrafinos, como efluentes, em forma de lama no Brasil no ano de 2015.

2. Metodologia

Este estudo está classificado de acordo com Vergara (2013) como descritivo e exploratório, sendo utilizadas as estratégias de pesquisa bibiográfica e documental, com abordagem quantitativa.

Foi realizado estudo bibliométrico sobre reaproveitamento de RRO nos artigos publicados nos últimos cinco anos na plataforma *ScienceDirect*, da Elsevier, com o auxílio do portal de periódicos da CAPES. O levantamento ocorreu no mês de dezembro de 2016 com o uso das palavras-chave *"granite", "marble", "ornamental stone", "natural stone", "ornamental rock"* e *"natural rock"*, associadas às palavras-chave *"residue", "waste", "powder", "dust", "sludge", "slurry"* e *"tailings"* (com suas respectivas formas no plural) através do uso do operador booleano *AND*.

A busca foi realizada em diversas etapas. Em cada etapa foram combinadas duas palavras-chave, por exemplo, *"granite" AND "residue"*, depois *"granite" AND "waste"*, etc. No total foram feitas 42 combinações de palavras-chave.

Após leitura e resumo dos artigos gerados pela busca, foram encontrados 108 artigos relacionados ao reaproveitamento do RRO. As informações dos 108 artigos selecionados foram exportadas para o *EndNote*®, e posteriormente convertidas em arquivo de texto, que foi exportado para o *Microsoft Excel*®, no qual foi realizada a análise dos dados e a confecção das tabelas e gráficos que compõem este estudo.

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3. Resultados

Para avaliar a dinâmica e a evolução da informação científica sobre o uso dos RRO e alcançar o objetivo deste estudo, que é identificar as alternativas para uma melhor destinação desses resíduos industriais, foi realizada leitura do título e resumo dos 108 artigos selecionados para serem classificados em diversas áreas de reaproveitamento. A tabela 1 apresenta o resumo dos resultados.

Tabela 1 - Resumo sobre as pesquisas atuais de reaproveitamento de RRO na plataforma *ScienceDirect*.

Nº	**Ano**	**Título**	**Aplicação**
1	2011	*Characterization of eco-cement paste produced from waste sludges*	Cimento
2	2011	*Cr-doped perovskite and rutile pigments derived from industrial by-products*	Pigmento inorgânico
3	2011	*Effect of mineral admixtures on properties of self-compacting concrete*	Concreto
4	2011	*Effects of the usage of diatomite and waste marble powder as partial replacement of cement on the mechanical properties of concrete*	Concreto
5	2011	*High-strength rice husk ash concrete incorporating quarry dust as a partial substitute for sand*	Concreto
6	2011	*Performance of self-compacting concrete containing different mineral admixtures*	Concreto
7	2011	*Predicting the core compressive strength of self-compacting concrete (SCC) mixtures with mineral additives using artificial neural*	Concreto

		network	
8	2011	*Recycled aggregate concrete produced with red granite dust as a partial cement replacement*	Concreto
9	2011	*Reuse of ornamental rock-cutting waste in aluminous porcelain*	Porcelana aluminosa
10	2011	*Reuse of sludge from the decorative quartz industry in hot bituminous mixes*	Asfalto
11	2011	*The use of solid residues derived from different industrial activities to obtain calcium silicates for use as insulating construction materials*	Tijolo
12	2011	*Use of waste marble aggregates in concrete*	Concreto
13	2011	*Utilization of muscovite granite waste in the manufacture of ceramic tiles*	Ladrilho cerâmico
14	2012	*An overview of using solid wastes for pigment industry*	Pigmento inorgânico
15	2012	*Characterization of stone powder sludge foams and their application to wastewater treatment: Role of pore connectivity*	Tratamento de água
16	2012	*Combining mineral and clay-based wastes to produce porcelain-like ceramics: An exploratory study*	Cerâmica
17	2012	*Effect of marble waste and pig slurry on the growth of native vegetation and heavy metal mobility in a mine tailing pond*	Tratamento de solo
18	2012	*Effect of natural pozzolana and marble powder on the properties of self-compacting concrete*	Concreto
19	2012	*Effectiveness of amendments on the spread and phytotoxicity of contaminants in metal–arsenic polluted soil*	Tratamento de solo
20	2012	*Estimation of compressive strength of self compacting concrete containing polypropylene fiber and mineral additives exposed to high temperature using artificial neural network*	Concreto
21	2012	*Fatigue behavior of dense asphalt mixes in dry and environmental-conditioning states*	Asfalto
22	2012	*Fresh and hardened characteristics of self compacting concretes made with combined use of marble powder, limestone filler, and fly ash*	Concreto
23	2012	*Investigation of using granite sludge as filler in bituminous hot mixtures*	Asfalto

24	2012	*Preparation and characterization of glazes from combinations of different industrial wastes*	Esmalte cerâmico
25	2012	*Probabilistic analysis of Mode II fracture of concrete with crushed granite stone fine aggregate replacing sand*	Concreto
26	2012	*Properties of concrete paving blocks made with waste marble*	Bloco de concreto
27	2012	*Properties of concrete prepared with low-grade recycled aggregates*	Concreto
28	2012	*Recycling of sawdust, spent earth from oil filtration, compost and marble residues for brick manufacturing*	Tijolo
29	2012	*Self-compacting concrete incorporating filler additives: Performance at high temperatures*	Concreto
30	2012	*The effect of fly ash content and types of aggregates on the properties of pre-fabricated concrete interlocking blocks (PCIBs)*	Bloco de concreto
31	2012	*The effect of mineral admixtures on mechanical properties, chloride ion permeability and impermeability of self-compacting concrete*	Concreto
32	2012	*Use of waste marble powder in brick industry*	Tijolo
33	2013	*An investigation on the influence of filler loading and compatibilizer on the properties of polypropylene/marble sludge composites*	Polímero
34	2013	*Carbon mineralization, microbial activity and metal dynamics in tailing ponds amended with pig slurry and marble waste*	Tratamento de solo
35	2013	*Characteristics of natural rubber hybrid composites based on marble sludge/carbon black and marble sludge/rice husk derived silica*	Compósito híbrido
36	2013	*Compressive strength of fly ash magnesium oxychloride cement containing granite wastes*	Cimento
37	2013	*Granitic quarry sludge waste in mortar: Effect on strength and durability*	Argamassa
38	2013	*Historical plasterwork techniques inspire new formulations*	Argamassa
39	2013	*Mechanical properties and corrosion resistance of concrete modified with granite dust*	Concreto
40	2013	*Polyester polymer concrete: Effect of the marble particle sizes and high gamma radiation doses*	Concreto
41	2013	*Properties of bricks made using fly ash, quarry dust and billet scale*	Tijolo
42	2013	*Strength and durability properties of concrete made with granite*	Concreto

		industry waste	
43	2013	*Sustainability perspective of marble and granite residues as concrete fillers*	Concreto
44	2013	*The effect of silica on the properties of marble sludge filled hybrid natural rubber composites*	Compósito híbrido
45	2014	*Adsorptive removal of methylene blue as organic pollutant by marble dust as eco-friendly sorbent*	Sorvente
46	2014	*Assessment of marble waste utilization as an alternative sorbent to limestone for SO2 control*	Sorvente
47	2014	*Blending of industrial waste from different sources as partial substitution of Portland cement in pastes and mortars*	Argamassa
48	2014	*Durability performance of structural concrete containing fine aggregates from waste generated by marble quarrying industry*	Concreto
49	2014	*Effects of mineral powders on hydration process and hydration products in normal strength concrete*	Concreto
50	2014	*Lead separation by sorption onto powdered marble waste*	Sorvente
51	2014	*Methodology for the mix design of self-compacting concrete using different mineral additions in binary blends of powders*	Concreto
52	2014	*Performance evaluation of cement mortars containing marble dust and glass fiber exposed to high temperature by using Taguchi method*	Argamassa
53	2014	*Portland cement systems with addition of sewage sludge ash. Application in concretes for the manufacture of blocks*	Bloco de concreto
54	2014	*Reinforcement of natural rubber hybrid composites based on marble sludge/Silica and marble sludge/rice husk derived silica*	Compósito híbrido
55	2014	*Restoration of dump deposits from quarries in a Mediterranean climate using marble industry waste*	Tratamento de solo
56	2014	*Re-use of waste marble dust in the production of cement and concrete*	Concreto
57	2014	*The effects of marble wastes on soil properties and hazelnut yield*	Tratamento de solo
58	2014	*Use of waste marble and recycled aggregates in self-compacting concrete for environmental sustainability*	Concreto
59	2014	*Using marble wastes as a soil amendment for acidic soil*	Tratamento de solo

		neutralization	
60	2015	*A study of the laboratory polishing behavior of granite as road surfacing aggregate*	Asfalto
61	2015	*An investigation on chloroprene-compatibilized acrylonitrile butadiene rubber/high density polyethylene blends*	Polímero
62	2015	*Changes in the chemical composition of an acidic soil treated with marble quarry and marble cutting wastes*	Tratamento de solo
63	2015	*Characteristics of fired clay bricks with waste marble powder addition as building materials*	Tijolo
64	2015	*Effect of graphite and granite dust particulates as micro-fillers on tribological performance of Al 6061-T6 hybrid composites*	Compósito híbrido
65	2015	*Evaluation of industrial based adsorbents for simultaneous removal of arsenic and fluoride from drinking water*	Tratamento de água
66	2015	*Homogeneity of filler distribution within asphalt mix – A microscopic study*	Asfalto
67	2015	*Hybrid composites prepared from Industrial waste: Mechanical and swelling behavior*	Compósito híbrido
68	2015	*Incorporation of fillers from marble and tile wastes in the composition of self-compacting concretes*	Concreto
69	2015	*Mechanical activation of natural acidic igneous rocks for use in cement*	Argamassa
70	2015	*Mechanical properties and microstructural analysis of cement mortar incorporating marble powder as partial replacement of cement*	Argamassa
71	2015	*Mechanical properties of structural concrete containing very fine aggregates from marble cutting sludge*	Concreto
72	2015	*Preparation and modification of nano calcium carbonate filler from waste marble dust and commercial limestone for papermaking wet end application*	Papel
73	2015	*Properties of cold bonded quarry dust coarse aggregates and its use in concrete*	Agregado para construção civil
74	2015	*Raw and treated marble wastes reuse as low cost materials for phosphorus removal from aqueous solutions: Efficiencies and mechanisms*	Tratamento de água
75	2015	*Sustainable use of marble slurry in concrete*	Concreto

76	2015	*Using marble sludge increases the success of dump deposit restoration under Mediterranean climate*	Tratamento de solo
77	2015	*Utilization of granulated marble wastes and waste bricks as mineral admixture in cemented paste backfill of sulphide-rich tailings*	Cimento
78	2015	*Utilization of hard rock dust with red clay to produce roof tiles*	Telha
79	2016	*Addition of quartzite residues on mortars: Analysis of the alkali aggregate reaction and the mechanical behavior*	Argamassa
80	2016	*Advancements in mechanical and physical properties for marble powder–cement composites strengthened by nanostructured graphite particles*	Argamassa
81	2016	*Clay-bricks from recycled rock tailings*	Tijolo
82	2016	*Durability properties of structural concrete containing very fine aggregates of marble sludge*	Concreto
83	2016	*Effect of granite dust on mechanical and some durability properties of manufactured sand concrete*	Concreto
84	2016	*Effect of low cost fillers on cement hydration*	Concreto
85	2016	*Effects of elevated temperature and water quenching on strength and microstructure of mortars with river sand substitutes*	Argamassa
86	2016	*Effects of marble sludge incorporation on the properties of cement composites and concrete paving blocks*	Bloco de concreto
87	2016	*Enhancement of concrete properties by waste physicochemical treatment sludge of travertine processing wastewater*	Concreto
88	2016	*Experimental investigation of surface modified EOF steel slag as coarse aggregate in concrete*	Concreto
89	2016	*Laboratory validation of a gradation design concept for sustainable applications of unbound granular materials in pavement construction*	Pavimento na construção civil
90	2016	*Lightweight aggregates from mixtures of granite wastes with clay*	Agregado para construção civil
91	2016	*Lightweight aggregates from waste materials: Reappraisal of expansion behavior and prediction schemes for bloating*	Agregado para construção civil
92	2016	*Metakaolin as a precursor of materials for applications in Cultural Heritage: Geopolymer-based mortars with ornamental stone aggregates*	Argamassa

93	2016	*Microbial growth and community structure in acid mine soils after addition of different amendments for soil reclamation*	Tratamento de solo
94	2016	*Performance of granite cutting waste concrete under adverse exposure conditions*	Concreto
95	2016	*Performance of sustainable concrete containing granite cutting waste*	Concreto
96	2016	*Potential of using granite waste as raw material for geopolymer synthesis*	Polímero
97	2016	*Preparation of calcium sulfoaluminate-belite cement from marble sludge waste*	Cimento
98	2016	*Production of price-competitive bricks using a high volume of stone powder sludge waste and blast furnace slag through cementless CaO activation*	Tijolo
99	2016	*Properties of NaOH activated geopolymer with marble, travertine and volcanic tuff wastes*	Polímero
100	2016	*Reinforcing concrete: comparison of filler effects*	Concreto
101	2016	*Removal of Cr(III) from chrome tanning wastewater by adsorption using two natural carbonaceous materials: Eggshell and powdered marble*	Tratamento de água
102	2016	*Reusing of marble and granite powders in self-compacting concrete for sustainable development*	Concreto
103	2016	*Rheological and mechanical properties of concrete containing crushed granite fine aggregate*	Concreto
104	2016	*Study of natural hydraulic lime-based mortars prepared with masonry waste powder as aggregate and diatomite/fly ash as mineral admixtures*	Argamassa
105	2016	*Sustainable utilization of granite cutting waste in high strength concrete*	Concreto
106	2016	*Crystallization behavior and properties of CaO-MgO-Al2O3-SiO2 glass-ceramics synthesized from granite wastes*	Vidro-cerâmica
107	2016	*Mineralogical study of granite waste in a pozzolan/Ca(OH)2 system: Influence of the activation process*	Cimento
108	2016	*Using marble sludge and phytoextraction to remediate metal(loid) polluted soils*	Tratamento de solo

Fonte: Elaborado pelos autores (2016).

A tabela 2 traz a quantidade e a porcentagem de artigos publicados por periódico, com seu respectivo fator de impacto JCR, que é um dos indicadores mais usados para classificar os periódicos acadêmicos.

Tabela 2 – Artigos publicados por periódico.

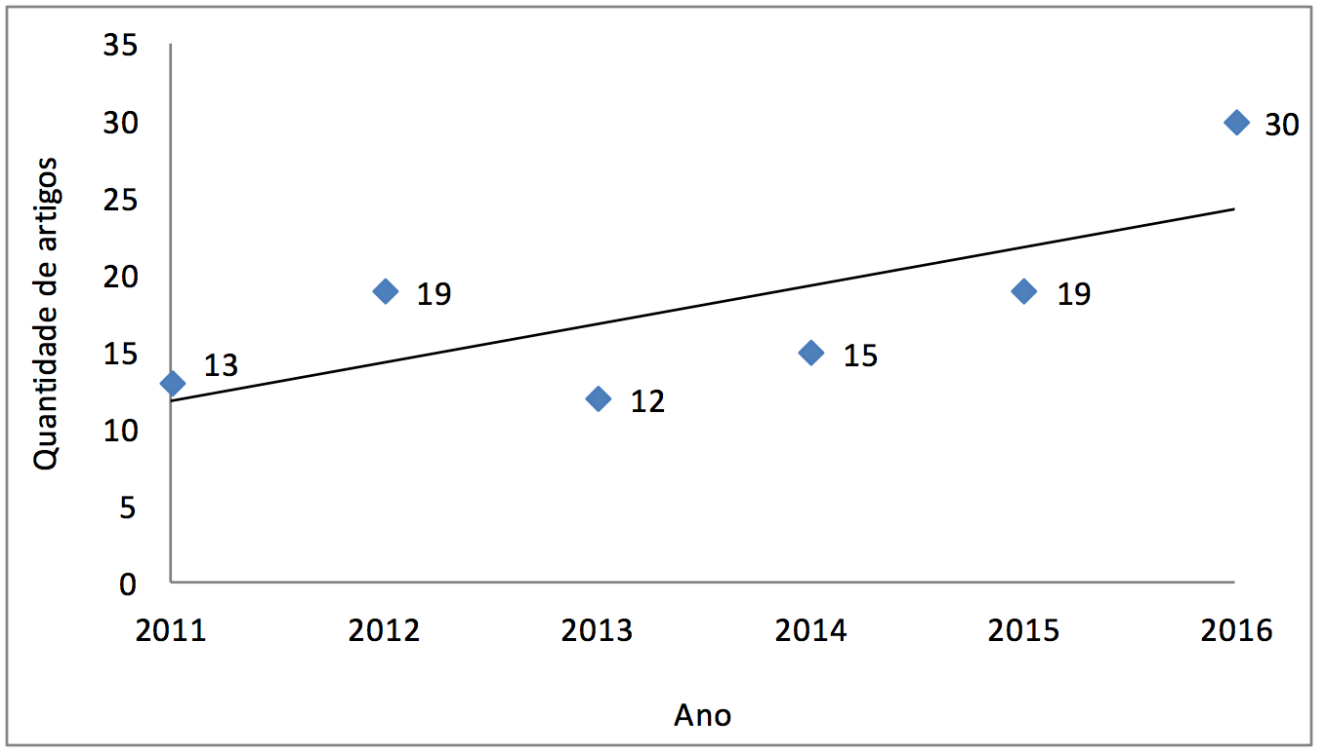
Periódico	**Quantidade de Artigos**	**Porcentagem**	**Fator de Impacto (JCR)**
Construction and Building Materials	50	46,3%	2,883
Journal of Cleaner Production	15	14,0%	5,315
Ceramics International	5	4,7%	2,661
Applied Clay Science	3	2,8%	3,065
Chemosphere	3	2,8%	4,068
Journal of Advanced Research	3	2,8%	-
Journal of Environmental Management	3	2,8%	4,049
Journal of Industrial and Engineering Chemistry	3	2,8%	3,458
Cement and Concrete Composites	2	1,9%	3,982
Ecological Engineering	2	1,9%	3,223
Journal of Geochemical Exploration	2	1,9%	2,749

Fonte: Elaborado pelos autores (2016).

Nota-se tendência da área de aplicação na construção civil, sendo o periódico *Construction and Building Materials* o que possui o maior número de publicações, totalizando 50 artigos. Também se destaca o periódico *Journal of Cleaner Production*, com 15 publicações, o que confirma a tendência das pesquisas atuais em destinar corretamente esses resíduos.

A figura 1 ilustra o número de publicações por ano, com sua linha de tendência. Nota-se aumento no número de publicações na área. O aumento do número de publicações sugere que há a preocupação das pesquisas atuais em destinar corretamente esses resíduos.

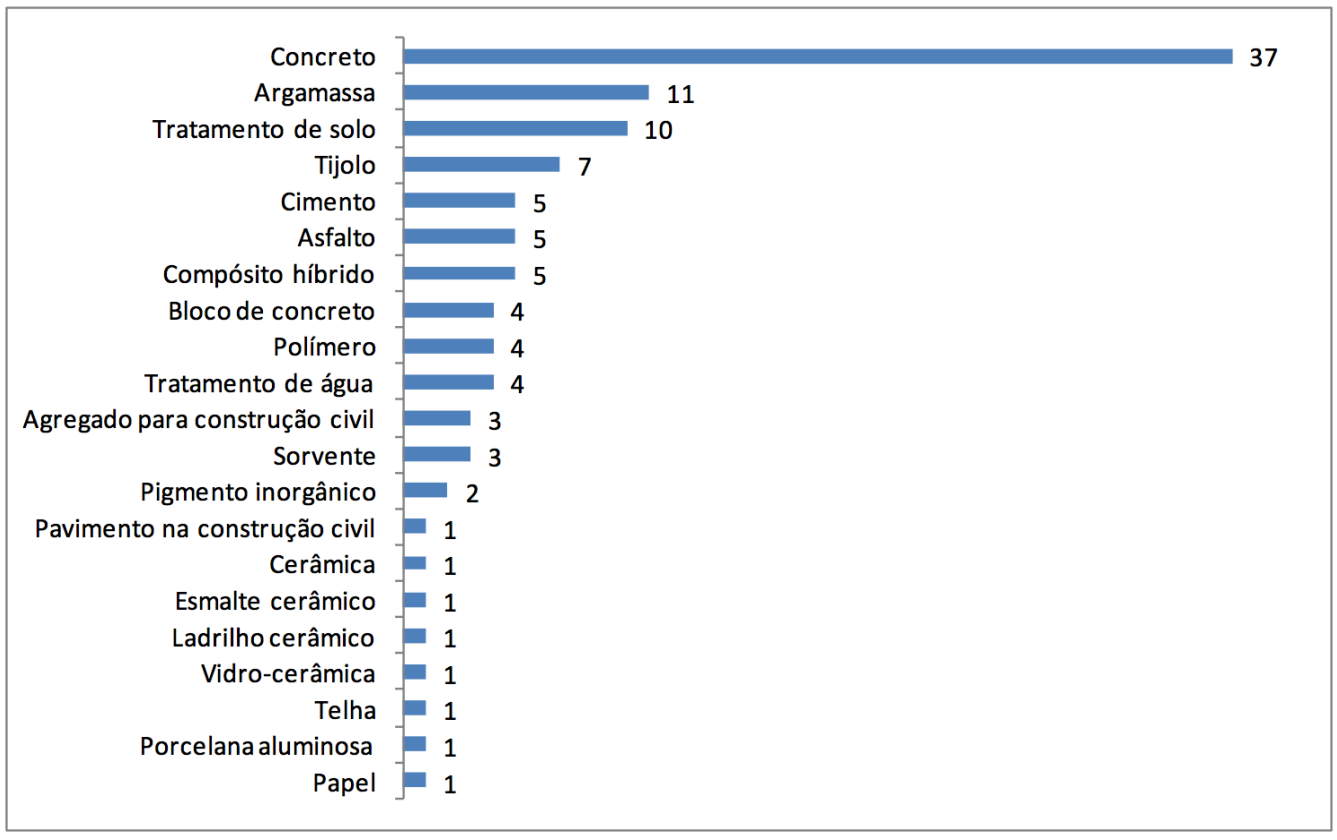
Figura 1 - Quantidade de artigos publicados por ano.



Fonte: Elaborado pelos autores (2016).

A figura 2 traz a quantidade de artigos publicados por área de aplicação. O gráfico evidencia um grande número de possibilidades distintas para o uso do RRO.

Figura 2 – Quantidade de artigos publicados por área de aplicação.

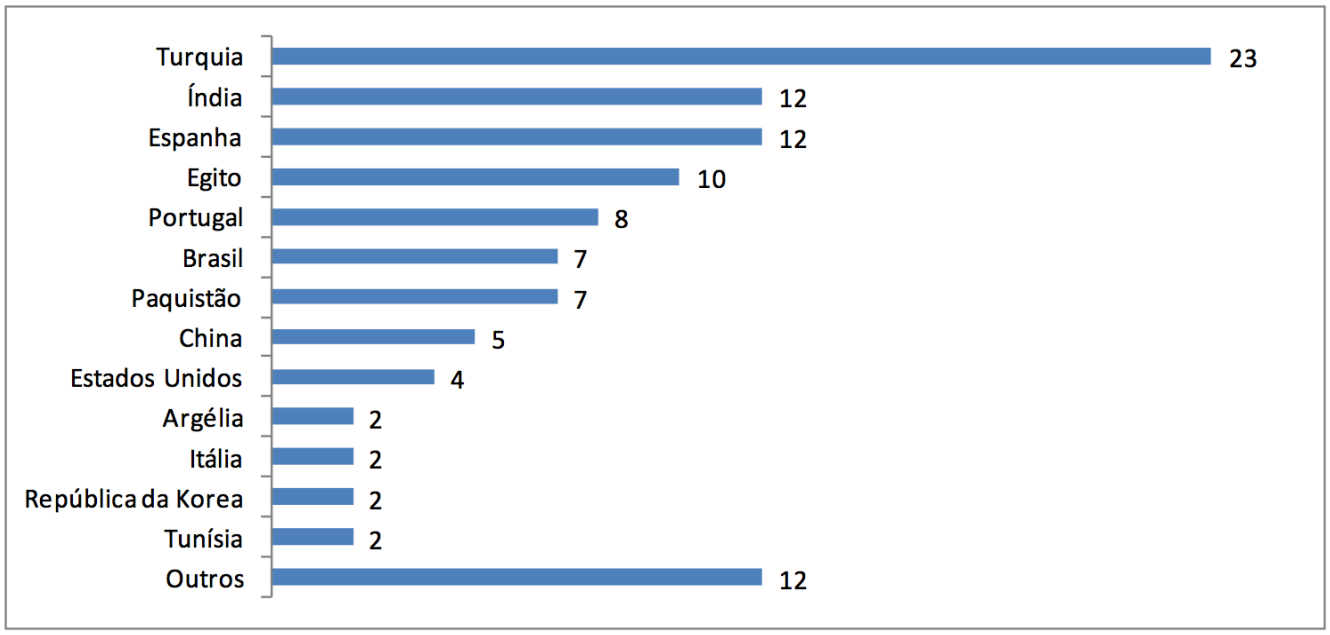


Fonte: Elaborado pelos autores (2016).

Nota-se que a maior quantidade de aplicações estudada envolve o uso do RRO no desenvolvimento de produtos sustentáveis para a área de construção civil (concreto, argamassa, cimento, bloco, agregado e pavimento) totalizando 61 artigos, e para a área de materiais cerâmicos (tijolo, cerâmica, esmalte, ladrilho, vidro-cerâmica, telha e porcelana) totalizando 13 artigos. A área de tratamento de solo também se destaca com 10 artigos. As áreas menos pesquisadas são a que envolvem seu uso para fabricação de sorvente químico, pigmento inorgânico e papel, respectivamente.

A figura 3 traz o número de publicações por país, sendo que 12 países possuem apenas uma publicação, e não foram considerados no gráfico.

Figura 3 – Quantidade de artigos publicados por região.



Fonte: Elaborado pelos autores (2016).

Nota-se que a maior quantidade de publicações foi realizada na Turquia, Índia e Espanha,

Evidenciando uma forte relação entre estudos sobre RRO com os grandes produtores mundiais de rochas ornamentais, visto que os países citados são o 3º, 2º e 7º maiores produtores mundiais de rochas ornamentais. (Montani, 2014).

4. Conclusões

Constatou-se que há tendência de aumento no número de publicações envolvendo o reaproveitamento dos resíduos de rochas ornamentais nos últimos anos. Destaca-se a diversidade de destinação dos RRO apresentada nos artigos, com destaque para as aplicações envolvendo o desenvolvimento de produtos sustentáveis para a área de construção civil e materiais cerâmicos. Em relação aos periódicos nos quais esses artigos estão sendo publicados, nota-se a mesma tendência da área de construção civil, sendo o periódico *Construction and Building Materials* o que possui o maior número de publicações. Observou-se ainda que maior quantidade de publicações têm origem na Turquia.

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Revista ESPACIOS. ISSN 0798 1015
Vol. 38 (Nº 29) Año 2017

[Índice]