



# Gender Balance in Construction Material Research: The Analysis of Alkali-Activated Materials by a Bibliometric Study Using Scopus Database

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Research in alkali-activated materials (AAMs) is an innovative and dynamic material science topic. This is due to the relevant performances in terms of physico-mechanical properties comparable to traditional construction materials (e.g., ordinary Portland cement). The sustainability of AAMs is often highlighted since they can be developed by using many natural or industrial by-products-based precursors. This leads to challenges with the optimization of AAM production due to their different performances, availability, and costs. However, they are flexible and locally adapted materials. The research interest in AAMs has rapidly increased in the early 2000s. In recent years, about 1,000 international articles have been published each year. This study aims at assessing the gender balance of this specific research topic to investigate the relevance of women's participation. Author lists of the published articles were analyzed throughout the Scopus database, applying "alkali-activated material" and "geopolymers" as keywords in the titles, abstracts, and keywords search. The last 10 years (2009–2019) were taken into account. The gender of the most prolific authors was analyzed, and a focus of European authors on this topic was considered, as more than 25% of the research in AAMs have been carried out in Europe. The analysis of 5,900 publications in the last decade shows that there is currently a shift toward men in the gender balance in this specific research, and female authors only covered 22% of the most productive authors worldwide. Considering European authors, a more equal gender distribution is reached, when the first author is considered, with a concentration of women in the range of 36–56%, recorded over 1,396 articles.

**Keywords:** geopolymers, gender balance, bibliometry, alkali activation, Scopus database, alkali activated materials

## INTRODUCTION

### Literature Review on Alkali-Activated Materials and Geopolymers

Nowadays, all around the world concrete is the main widely employed construction material. Moreover, its consumption is constantly increasing, due to its rising demand in developing countries. On the other hand, the production of cement has a huge impact on the environment. Worldwide, it has been estimated that the cement sector is responsible for nearly 8% of all carbon dioxide (CO<sub>2</sub>) emissions caused by anthropic actions. Indeed, it is well known that the manufacturing of 1 ton of Portland cement implies the emission of almost the same amount of CO<sub>2</sub> in atmosphere, although

during its entire life cycle, carbonation of cement allows for CO<sub>2</sub> sequestration (for a cumulative amount of 4.5 GtC measured between 1930 and 2013) and determines an adjustment of CO<sub>2</sub> emissions (43% calculated considering the same period) related to cement production (Xi et al., 2016). Moreover, taking into account the period of time from 1990 to 2050, a rise in cement manufacturing of nearly 250% is expected (Imbabi et al., 2012; Scrivener et al., 2018), even if economic crisis due to external factors (e.g., COVID emergency) may locally modify this scenario.

The first use of the term “alkali activation” dates back to 1908, but only in the 1930s–1950s Purdon carried out some work on this technology in Belgium (Palomo et al., 2014; Provis, 2014). The real development of alkali activation was due to an extensive research program by Glukhovskiy starting from the 1950s (Provis, 2014). The term “geopolymer” was introduced in the 1970s by Davidovits, indicating the alkali activation of metakaolinite, limestone, and dolomite (Palomo et al., 2014).

Especially in the last two decades, alkali-activated materials (AAMs), including geopolymers, have quickly caught people’s interest, in order to reduce CO<sub>2</sub> emissions due to cement and ceramic material productions (Provis, 2014; Pacheco-Torgal et al., 2017; Sandanayake et al., 2018; Asim et al., 2019; Rakhimova and Rakhimov, 2019b; Shi et al., 2019; Singh and Middendorf, 2020). Alkali activation is the general expression used for the reaction of a precursor (i.e., a solid aluminosilicate) in an alkaline environment sourced by alkali activators to obtain a hardened binder mainly based on hydrous alkali aluminosilicate. This explanation can even include low amount of traditional cement together with elevated combinations of blast furnace slag or pozzolans. However, when cement is the principal origin of alkalinity, these kinds of binders are not considered in the alkali activation nomenclature (Bignozzi and Bonduà, 2011). Moreover, the term geopolymer is largely used, sometimes also in a quite indiscriminate way, to account for low calcium AAMs. Finally, hybrid binders containing both cement and a source of alkalis together with aluminosilicate elements have also been developed. Nevertheless, in general, all these systems may be considered as part of the wider field of alkali activation (Provis and Bernal, 2014; Provis et al., 2015; Provis, 2018; Provis and van Deventer, 2019; Shi et al., 2019).

AAMs can be synthesized by two main routes: i) a one-part mix (dry precursors and activators activated by water) and ii) a two-part mix (dry powder combined with activating solutions) procedure. Alkali activation by the two-part mix approach has been for sure the most investigated and used in the first applications of alkali activation-based products introduced in the market. The two-part mixture is used in the precast production, where packaging and transporting of chemical substances, together with curing conditions, can be managed at a close range (Provis, 2018; Singh and Middendorf, 2020). On the other hand, studies are being carried out to improve the one-part methodology and to develop products suitable for the market, so this methodology would be widely employed henceforth (Luukkonen et al., 2018).

As solid precursors for the production of AAMs, typical aluminosilicate supplementary cementitious precursors can be

used (Rakhimova and Rakhimov, 2019a), including blast furnace slag, coal fly ash (Zhuang et al., 2016), calcined clays, and natural pozzolans (Robayo-Salazar and Mejía de Gutiérrez, 2018) that have shown high-quality outcomes. Blast furnace slags used in alkali activation need to be granulated and ground. Additions exhibiting pozzolanic behavior, generally utilized in cement blends only to a lower extent, can be suitable for alkali activation as well. Various types of slags (cooled until a reactive condition and finely ground), sludges coming from industrial processing, ashes of different nature and origin (Hertel and Pontikes, 2020), etc., can also be employed in alkali activation, ensuring their safe use in terms of leachability of potentially toxic elements (Provis, 2018; Singh and Middendorf, 2020). As alkali activators, M<sub>2</sub>O·rSiO<sub>2</sub> and MOH (with M = Na or K) are the most utilized chemicals (Silva et al., 2017; Provis, 2018; Rakhimova and Rakhimov, 2019a).

Inter-grinding or co-calcination of different aluminosilicate powder precursors and solid activators have been demonstrated to be effective in the synthesis of one-part AAMs, thus promoting their development (Luukkonen et al., 2018; Provis, 2018).

The great variability of precursors and activators available worldwide does not allow one to design one or more model mixes that are always applicable; thus, studying fundamental rules to properly set up *ad hoc* mix designs together with a precise quality control and characterization of the starting materials is a challenge that needs to be addressed. The control of setting time, the choice of suitable admixtures, and the curing conditions are some of the features under investigation. For example, when a low quantity of calcium was present in the fly ash used as precursor, alkali activation at room temperature obtaining outstanding mechanical properties was demonstrated (Bignozzi et al., 2014). At the same time, also clay-based binders can harden quickly at room temperature; however, the amount of water added, as function of particle size, can strongly influence the setting time and workability. Generally speaking, sealed curing is highly indicated for AAMs.

A large number of AAMs and geopolymers have been studied so far, from the point of view of chemical, microstructural, physical, mechanical, and durability performances of precursors and hardened products (Bignozzi et al., 2013; Masi et al., 2014; Singh et al., 2015; Ma et al., 2018; Zhang et al., 2018; Hassan et al., 2019; Li et al., 2019; Tang et al., 2019; Wu et al., 2019; Saccani et al., 2020; Mugahed Amran et al., 2020); however, it is still difficult to think that alkali-activated binders will soon be ready for complete substitution of cement in all the applications where it is normally involved. AAMs are surely attractive for their potentially high degree of sustainability, especially when they are obtained with raw materials and/or waste locally available, without requiring thermal and/or specific separation treatments (Pacheco-Torgal et al., 2017; Rakhimova and Rakhimov, 2019b; Shi et al., 2019; Singh and Middendorf, 2020).

The field of application of AAMs is broad (Wu et al., 2019), and is still increasing, with exploitations in renders, grouts, mortars, lightweight and foamed concrete (Carabba et al., 2019a), precast concrete elements, plain and reinforced concrete (Kamseu et al., 2014; Monticelli et al., 2016a;

Monticelli et al., 2016b; Mo et al., 2016; Carabba et al., 2017b; Tittarelli et al., 2018; Hassan et al., 2019), pipes, or matrix for nuclear or toxic waste immobilization (Rasaki et al., 2019; Singh and Middendorf, 2020). Moreover, features such as high temperatures and chemical attack resistance make AAMs particularly attractive for specific applications such as refractory blocks, passive fire protection systems, and sewer pipes (Pacheco-Torgal et al., 2012; Masi et al., 2015; Carabba et al., 2017a; Carabba et al., 2019b; Rashidian-Dezfouli and Rangaraju, 2017; Zhang et al., 2017; Ameri et al., 2019; Carabba et al., 2019b; Lahoti et al., 2019; Wang et al., 2020).

## Gender Equality in Material Science

Gender equality represents a major issue in all science, technology, engineering, and mathematics (STEM) fields. Traditionally, women are underrepresented in these sectors. Among the others, women underrepresentation in material science and engineering is an historical problem (The University Materials Council, 2008; Larivière et al., 2013). In addition, the trend related to the presence of women decreases especially at the highest level of academic careers or when high responsibility positions are considered within scientific decision-making bodies (European Commission, 2008; European Commission, 2010).

Considering all the fields of life, in the last 5 years in Europe, some improvements have been achieved (European Commission, 2015): women's employment reached 64% (the highest rate ever recorded) and an improvement in the presence of women was recorded in decision-making positions in many spheres of life (+9% of women as board members in the biggest listed companies). These results are related to some of the policies sponsored by the European Commission in the first years of the 2000s. In particular, the Commission's 2010–2015 strategies for bridging the gender gap consisted in the following principles: equal economic independence for women and men; work of equal value shall be equally paid; decision-making, dignity, integrity, and ending gender-based violence are equally assessed; and last, gender equality is promoted beyond European Union (EU) (European Commission, 2015). It was demonstrated that major improvements were achieved in those countries where introduced legislative measures were properly addressed (European Commission, 2015). In addition, in the early 2000s, a group of women scientists was involved in a European Technology Assessment Network group to explore and make recommendations on the issue of women in science in Europe. The European Technology Assessment Network group proposed three models to promote gender equality, which consisted of equal treatment between men and women, positive action, and mainstreaming (Rees, 2001). In particular, they identified gender mainstreaming as the most positive action for a long-term strategy, in order to contribute to bridging the gender balance. This was because equal treatment refers to individuals' rights with the aim of equality, and a positive action can partly improve the gender gap. On the contrary, gender mainstreaming can recast the systems and structures themselves that currently advantage men. In addition, several recommendations, mainly focused on the science, engineering, and medicine sectors, have been

proposed to promote gender equity, in terms of direct economic support, strategies related to psychology and culture, and major collaborative and international motivations (Smith et al., 2015).

However, gender inequalities are still present in education and in occupations, especially in STEM and related careers in the EU and worldwide (Shen, 2013; European commission, 2015; Kang et al., 2019; Stoet and Geary, 2018). Many factors influence these differences. First, gender inequalities in education still persist, in terms of study subject preferences, performance, and participation (Kang et al., 2019; Stoet and Geary, 2018). At the age of 11 or 12 years, students begin their career aspirations which will be developed on the basis of their studies during the secondary school. In particular, the perception of STEM careers by females is generally stereotyped, as it is perceived with less time for oneself and as an obstacle for achieving the traditional life goals (family, children, etc.). For these reasons, higher involvement in scientific subjects in schools could help bridge the gender gap in the selection of future careers (Kang et al., 2019). In addition, women are more likely to have a higher education (even, if according to the United States National Science Foundation, grants for women are about half of the grants for men during their doctorates in the United States), but female scientists still face major challenges [e.g., in United States, women represent only 21 and 5% of full science and full engineering professors, respectively (Shen, 2013); in Italy, female full professors in the scientific sector of "materials science and technology" are only 26% (<https://cercauniversita.cineca.it/>)]. One of the most persistent issues is that a large part of qualified female researchers quit in the early stages of their science careers. This is mainly linked to several aspects, such as family values (women in postdoc positions drop out of research careers when they become parents or plan to have children, up to twice as often as men with families), life issues and discriminations, and pay problems (in the EU public sector, women in science earned 25–40% less than male scientists in 2006) (Shen, 2013).

One of the tools to investigate gender distribution in any field of science and engineering is the study of journal authorship, journal editorial boards, and the extent of collaborations, due to the fact that generally journal publications are the main outcomes indicating scientific and technological productivity, as well as the main channel for communicating new knowledge (Larivière et al., 2013; Mauleón et al., 2013; West et al., 2013). A cross-disciplinary bibliometric study on the relationship between gender and research outputs by Larivière et al. highlighted that men dominated in scientific production in nearly every country worldwide and women were underrepresented, especially when first authorship was considered (Larivière et al., 2013). Moreover, another research analyzed the gender distribution in paper authorship, as well as the compositions of editorial boards of Spanish journals in the years between 1998 and 2009 (Mauleón et al., 2013). They found that female presence was lower than that of men, but the gender gap was narrowing in the last period of the analysis, indicating a higher participation and recognition of women. Finally, a bibliometric study based in the United States using JSTOR corpus highlighted an increase of women

in the authorships (27% in 1990–2012 vs. 15% in 1665–1989) and in obtaining higher education degrees (64% of PhD recipients are women in 2004), especially in the first years of the 2000s (West et al., 2013). However, women were still underrepresented in tenure track and research university faculty positions (only 39% in full-time positions). Finally, West et al. demonstrated that whereas, historically, women were underrepresented in the first author positions in journal-article author lists, the situation was more equal in terms of first author, while a gender gap remained when last author positions and single-author articles were considered (West et al., 2013).

## Aim of the Study

As previously mentioned, research in AAMs is nowadays a proficient and very active research sector of material science, which is a very broad research field. In addition, this specific topic has recently seen a quick increase in terms of scientific interest and number of published articles and involves many aspects, applications, and research backgrounds (chemistry, material and civil engineering, etc.). AAMs exhibited strong development as a possible replacement of ordinary Portland cement in the construction sector, due to the sustainability features of the production of these materials (Provis, 2018). Traditionally, construction and construction material production are a male-dominated sector. A study by Paul et al. (2020) on gender balance in the European cement industry showed that female authors gain some achievement in terms of presence in scientific publications. Especially it was found that women are very active and involved in the development of strategies to increase sustainability features in cement production. However, women are still underrepresented in this specific sector, and only 33% of contributions are from female authors. Last, due to the relatively recent sensitivity to the gender balance issue and to the increasing involvement of women in research, a quick increase in the selection of a topic such as AAMs in the last two decades may represent a very good opportunity for monitoring the growing presence of female researchers in material science, specifically in the building sector. For all these reasons, the analysis of gender distribution based on a bibliometric study was performed using the Scopus database, including indexed articles on peer-reviewed journals, conference proceedings, and books. This shall be a representative scenario describing gender balance in one specific field of material science. Beyond numerical and geographical distribution of the research outputs, analysis of the gender of the most prolific authors (first 100) in the last decade, between 2009 and 2019, was reported. Last, the European scenario was also discussed in detail, analyzing gender equity in terms of first and last positioned authors in the author lists. This choice was because usually the most important contributors to articles are found in the first and last positions (with one usually overlapping with the name of the corresponding author), especially when some scientific areas (including material science) are considered (Kosmulski, 2012; Simoes and Crespo, 2020). Accordingly, in this study, the corresponding author role was excluded in the analysis as it often coincides with the first author. In addition, the first author is generally the most involved researcher in a specific study, i.e.,

performing laboratory testing (if any) and writing the main body of the paper, while the last author is usually the one who conceptualizes the research study and/or the director of the research laboratory. Moreover, even if different author orders can be also applied, for example, the alphabetic order when all authors provide the same contribution to the study, this represents more the exception rather than the rule in article publishing. Finally, the impact of the research based in Europe was considered through analysis of the citations of the research outputs, as well as the correlation with gender distribution.

## MATERIALS AND METHODS

The bibliometric study was carried out using the Scopus database (<https://www.scopus.com>). This database indexes content from 24,600 titles and 5,000 publishers which are selected by an independent review board. Scopus generates precise citation results and detailed researcher profiles. Moreover, the selected database takes into consideration only indexed research products; thus, non-peer-reviewed papers published in conference proceedings and articles published in non-indexed journals are not considered in this study.

The keywords used for the bibliometric research were “alkali activated materials” or “geopolymers.” In order to refine the results and be sure that all the documents were related to the specific topic, a first refinement of the results was carried out selecting only English language articles, reviews, and conference papers in order to analyze international research studies. A second refinement was based on selecting further keywords with the aim of a more precise delimitation of the topic. In particular, the following keywords were considered: “inorganic polymer,” “geopolymer(s),” “alkali activated,” “geopolymer concrete,” “geopolymer composites,” “geopolymer binders,” “alkali-activated binder,” “alkali-activated cement,” “geopolymerization,” “alkali-activated slag,” “geopolymer mortars,” “alkaline activation,” “geopolymer materials,” “geopolymer matrix,” “geopolymer cement,” and “alkali-activated fly ash.” These refinements allowed us to bring down the number of documents to be analyzed from more than 8,000 to 5,900 documents.

The analysis was carried out as follows: i) the trend of the published articles and the geographical distribution of the authors were processed by the “Analyze search results” tool available in Scopus. ii) The analysis of gender balance was carried out for the first 100 most prolific authors for each year. In order to correctly define the gender of the authors, each author profile was checked using the Scopus database and/or ResearchGate web page (<https://www.researchgate.net/>) and/or Google Scholar database (<https://scholar.google.com/>), in which author profile pictures are also usually reported, thus making gender recognition easier. When no information about the author profile (e.g., first name and picture) was available, the specific author was categorized as “undefined.” iii) Only for European authors, gender analysis of the first and last authors was carried out considering each author profile. As previously reported, first and last positioned authors usually play the most important roles in manuscript writing and in research development. Moreover, a

correlation with the number of citations was also considered to analyze the impact of the publications related to gender distribution. Number of citations for each article was recorded on May 6th, 2020, on the Scopus database web page.

## RESULTS AND DISCUSSION

The following section reports the results of the bibliometric study on gender balance in the field of AAMs, including geopolymers. First, numerical and geographical distribution of published articles is reported. Then, gender analysis of the most prolific authors worldwide is discussed. Last, analysis of the gender balance of European authors is shown, considering first and last authors in the author list, as well as the correlation between author gender and number of citations.

### Numerical and Geographical Distribution of Published Articles

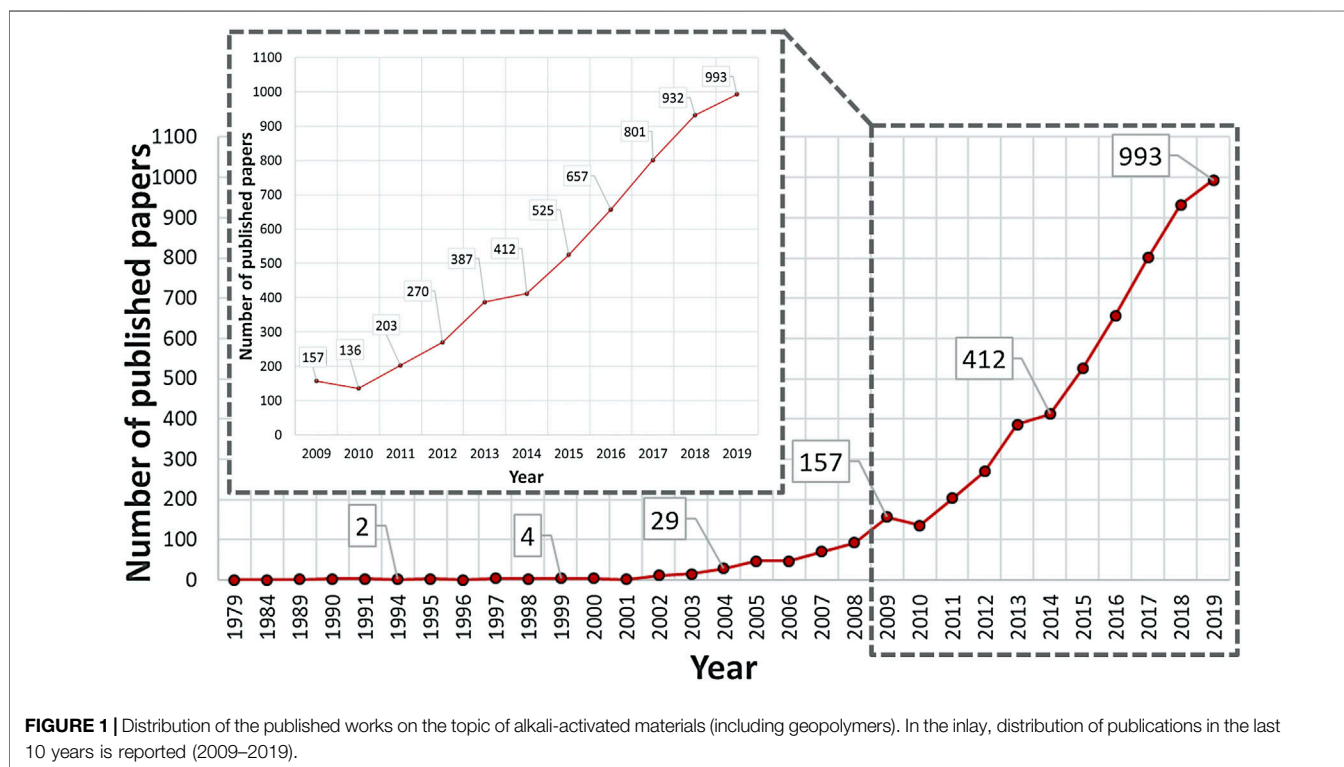
The first publication on geopolymers dates back to 1979 by Davidovits. However, only in the first years of the 2000s, this specific research topic started attracting research interests, as depicted in **Figure 1**, probably due to an increasing attention to environmental pollution problems and the consequent need to reduce CO<sub>2</sub> emission in building material production. Especially in the last decade, there has been an exceptional increase in research interest about AAMs (including geopolymers), as demonstrated by the increasing linear trend of published articles between 2009 and 2019 (inlay of **Figure 1**).

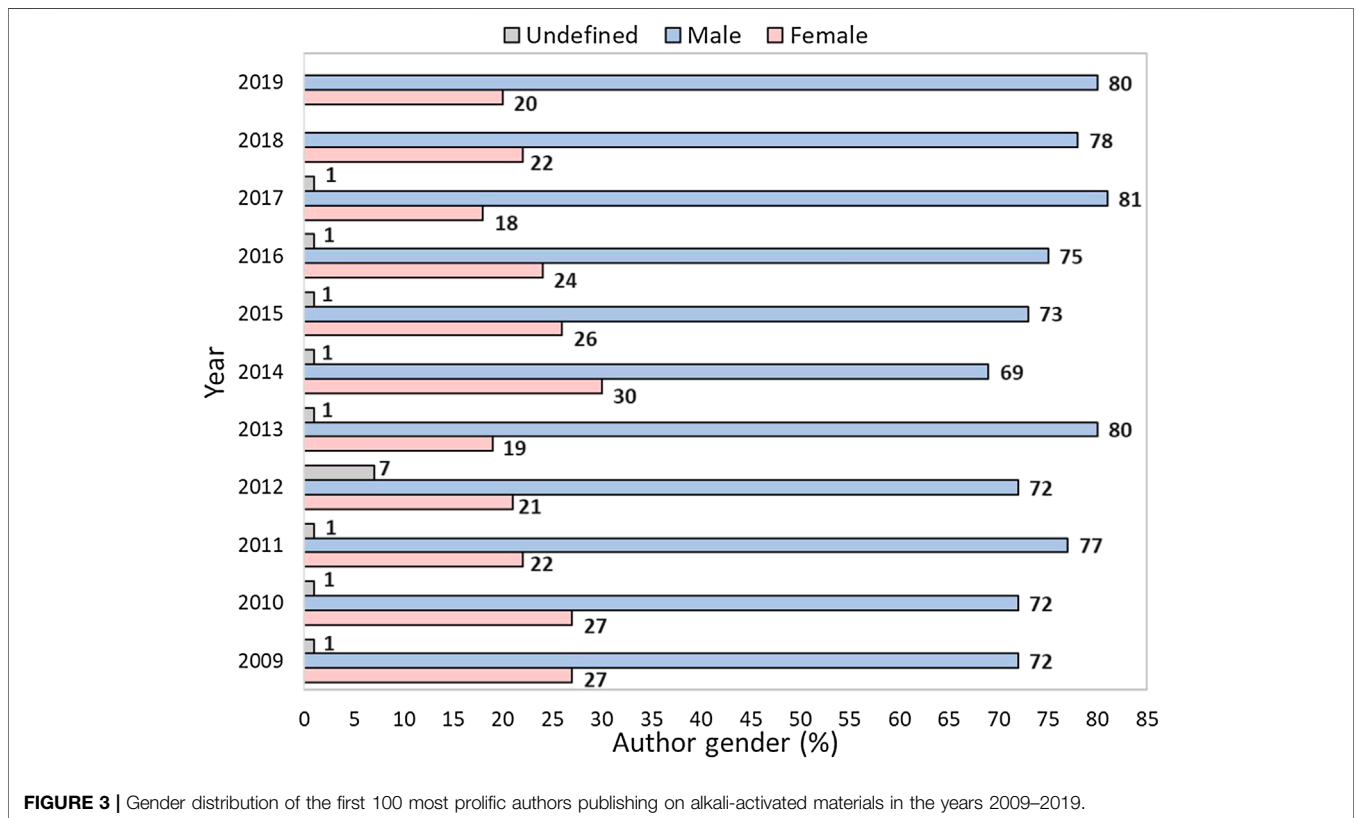
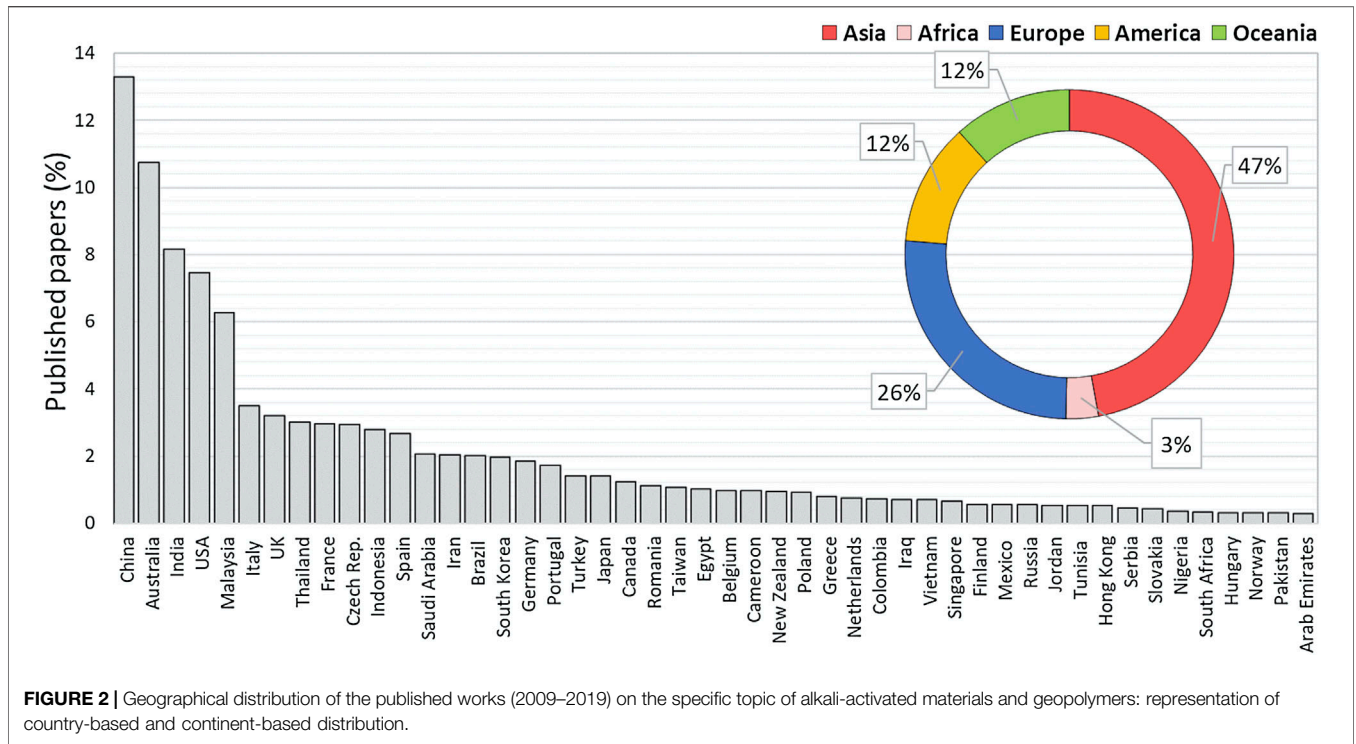
Specifically, in 2019 almost 1,000 articles were published in scientific peer-reviewed journals and international conference proceedings, highlighting that research on this topic is still strongly active all over the world. Due to this trend in the last 10 years, further analyses about geographical distribution and gender balance were carried out considering only the period between 2009 and 2019.

Geographical distribution of the articles on AAMs published between 2009 and 2019 is shown in **Figure 2**. Most of the articles were published by Chinese (13%), Australian (10%), and Indian (8%) researchers. In detail, about half of the publications on AAMs were based in Asia (47%), mainly in China, India, Malaysia, Thailand, and Indonesia. In addition, 26% of the publications were based in Europe, most of them in Italy, United Kingdom, France, the Czech Republic, and Spain, while 12% were publications from America and Oceania. Finally, only 3% of the publications were from African researchers, mainly based in Egypt, Cameroon, Tunisia, Nigeria, and South Africa.

### Gender Balance of Most Prolific Authors

A record of about 5,900 publications was analyzed to investigate the gender balance of the most prolific authors with a focus on each year in the last decade (2009–2019). The analysis took into account 595 authors, and among them, only 144 authors were females (24%), against 434 male authors (73%) (for 17 authors (about 3%), the gender was not identified). The distribution of author gender of the most productive researchers for each year is reported in **Figure 3**. No specific trend was observed. The gender





distribution is similar to the one determined for the 5,900 publications, showing a female author rate ranging between 19% in 2013 and 30% in 2014. Surprisingly, in the last 5 years, an increase in women as most prolific authors was not observed, thus indicating that women have less opportunity or interest in publishing the results of their research or, alternatively, the number of women involved in building material science is still rather limited. Moreover, the fact that no specific trend of gender distribution was observed can be ascribed to the limited range of time considered in this study, due to the recent development of the research topic taken into account. Even if this specific topic has been mainly prolific in the last decade, the analyzed situation exhibited only one generation of researchers. Thus, this kind of analysis should be repeated for the next decades in order to monitor the gender distribution, and hopefully a significant increase in female authors among the most prolific researchers could be recorded. This result would be significant to reach a more equal gender distribution in this specific field of material science.

## The Case Study of Publications by European Authors

In order to deeply examine the gender distribution of authors involved in AAM research, a case study of publications with at least one European author was considered. In this specific case, a total record of 1,386 publications in the period 2009–2019 was analyzed: **Table 1** reports the type and distribution of the considered publications. In particular, most of the outputs are articles published in international peer-reviewed journals (74%). The remaining part is split as follows: 23% publications in international conference proceedings and only 3% of the publications are reviews.

Generally speaking, the number of all the publication types increased from 2009 to 2019, except for conference proceedings where a more alternate trend is detected. This peculiar behavior can be ascribed to the fact that international conferences are rarely scheduled every year, with biennial frequency being the most popular solution for many important congresses in the material sector (e.g., International Conferences on Modern Materials and Technologies, conferences organized by the European Ceramic Society and the American Ceramic Society, American Concrete Institute conventions, and International Conference on Advanced Ceramics and Composites). Moreover, at the moment, AAMs (including geopolymers) are usually included in one-day specific sessions inside conferences covering broader topics (such as ceramics, cement, and concrete)

and specific congresses on these are only a few (e.g., Engineering Conference International on AAMs, the Geopolymer Camp organized by the Geopolymer Institute, and International Conference on Non-Traditional Cement and Concrete at BRNO in Czech Republic).

It is further highlighted that open access (OA) publications represent 18% of publications by European authors, with an increasing trend in the last decade. In particular, from 2013, the number of OA publications continuously increased up to 26% in 2018 and 2019. OA publications provide free online access of scientific information, thus following European recommendations. Nowadays, in fact it is recognized that more accessible research results have the positive impact to produce better and more efficient science. Especially the EU Commission policies have encouraged and supported OA publications at the international level as demonstrated in the framework of its Research and Innovation Programmes, such as Horizon 2020 (European Commission, 2017).

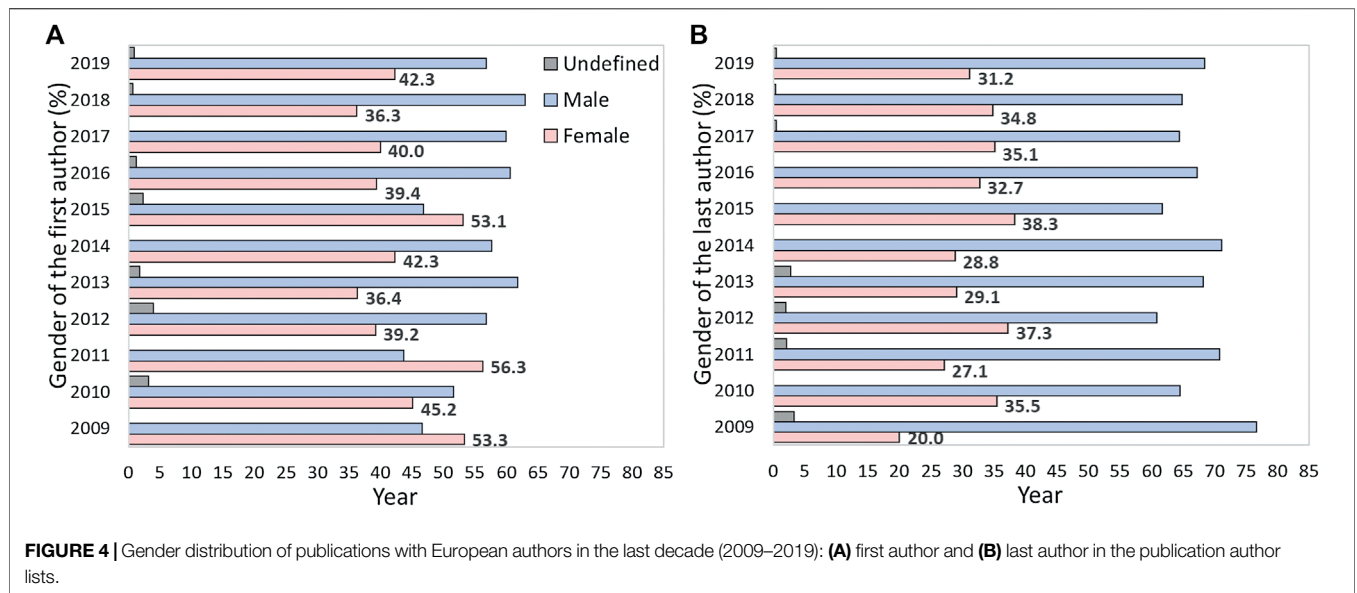
Finally, only 1.4% of the total publication by European authors are by single authors, highlighting the interdisciplinary and collaboration research aspects characteristic of the material science sector.

Regarding the gender distribution of the European authors in 2009–2019, analysis of the record was carried out considering both first and last author positions in the author lists. These are key roles in research, as previously explained, usually representative of the active and responsible figure and the manager of the specific research, respectively. For this reason, generally speaking, it is possible that most of the first authors are researchers in an early-stage career, while expert researchers and professors are usually located in the last author position.

**Figure 4** reports the gender distribution regarding the European authorships of the first (**Figure 4A**) and last authors (**Figure 4B**) in articles published in 2009–2019. Unlike that reported for most productive authors publishing on AAMs worldwide (**Figure 3**), the case of European authors shows a higher participation of women in publications. In particular, for first authors in the author lists, a concentration of women in the range 36–56% was recorded (**Figure 4A**). Even if no specific trend was exhibited in the last decade, these results are encouraging as they are almost double of those observed worldwide and can be considered an interesting result of the policies of EU only recently strongly addressed to promote gender balance. As previously mentioned, first authors generally correspond to researchers in an early-stage career; thus, the actual and future European policies for enhancing excellence in research would help and encourage

**TABLE 1** | Type of publications based in Europe on alkali-activated materials (including geopolymers) in the last decade (2009–2019).

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
Total publications	30	31	48	51	110	111	128	165	205	273	234	1,386
Journal articles	17	20	30	39	86	74	104	123	148	193	194	1,028
Conference proceedings	13	11	14	7	24	31	21	38	50	72	34	315
Review	—	—	4	5	—	6	3	4	7	8	6	43
Open access	1	—	—	—	11	12	17	38	41	70	62	252
Single author	—	—	2	2	3	2	3	—	6	5	6	19



the most valued researchers to continue in their careers. On the other hand, analysis of the gender distribution of the last authors (**Figure 4B**) shows a lower concentration of women in the last author position than in the first author one, thus confirming that women in high positions (full professor, manager of laboratory, etc.) are still a minority. This situation is, however, better than that reported for most prolific authors worldwide, being the range between 20 and 38% (**Figure 3**). The trends in **Figures 4A, B** (showing near equity in the first author position and the low

amount of women in the last author position) agree with those reported in a previous study developed in the United States regarding several research fields (*West et al., 2013*).

Moreover, an analysis of the citations of publications about AAMs in which the first or last European authors were represented by women was carried out to highlight the impact of the publications. Results are reported in **Table 2** considering the last decade (2009–2019). Generally speaking, higher percentages of women are found for number of citations lower

**TABLE 2 |** Correlation between female authors and the number of publication citations (data refer to papers published in 2009–2019).

Year	Author list position	Number of citations									
		>100		50–100		10–50		<10		None	
		Publications	Women (%)	Publications	Women (%)	Publications	Women (%)	Publications	Women (%)	Publications	Women (%)
2009	First author	4	25.0	5	60.0	10	50.0	8	87.5	3	0.0
	Last author		25.0		20.0		30.0		12.5		0.0
2010	First author	5	20.0	6	66.7	7	28.6	11	54.5	2	50.0
	Last author		40.0		16.7		28.6		45.5		50.0
2011	First author	8	50.0	7	71.4	17	58.8	12	58.3	4	25.0
	Last author		0.0		42.9		23.5		25.0		50.0
2012	First author	2	0.0	10	20.0	24	41.7	14	57.1	1	0.0
	Last author		0.0		10.0		37.5		57.1		100.0
2013	First author	4	100.0	23	39.1	56	30.4	23	30.4	7	42.9
	Last author		0.0		21.7		39.3		13.0		28.6
2014	First author	9	44.4	8	37.5	48	47.9	40	32.5	7	57.1
	Last author		22.2		50		27.1		27.5		28.6
2015	First author	3	0.0	15	46.7	69	53.6	36	58.3	5	60
	Last author		33.3		33.3		37.7		44.4		40
2016	First author	—	—	15	26.7	86	37.2	51	43.1	13	53.8
	Last author		—		33.3		33.7		29.4		38.5
2017	First author	—	—	2	50.0	109	31.2	50	44.0	13	53.8
	Last author		—		50.0		29.4		30.0		38.5
2018	First author	1	0.0	1	0.0	91	38.5	134	36.6	36	41.7
	Last author		0.0		0.0		34.1		33.6		44.4
2019	First author	—	—	1	0.0	18	27.8	138	41.3	76	48.7
	Last author		—		0.0		27.8		31.2		31.6



than 100 and female author in the first position. However, in the years 2011, 2013, and 2014, noteworthy percentages of European women as first authors are found in publications with more than 100 citations. Less relevant is the percentage related to women in the last author position with a high number of citations, even if some exceptions are observed (e.g., 2017: 50% of European female last authors with number of citations in the range of 50–100; 2015: 33.3% of European female last authors with number of citations >100). These results agree with previous results indicating that researchers in the early-stage careers, represented by first authors, are more equally gender distributed also in highly cited publications.

## CONCLUSIONS

The following conclusions can be drawn from this study:

- AAMs, including geopolymers, is a new material science field in which the research is prolific and innovative. Especially in the last decade, a continuous growth in publications in international peer-reviewed journals and in international conference proceedings was detected;
- publications on AAMs are mainly based in Asia (about 50%), even if Europe (about 26%) is largely involved in this specific topic;
- the analysis of gender distribution of the most productive authors worldwide showed that only 22% of the total authors are women;
- considering European authors, a more equal gender distribution is reached when the first author is considered. This trend is also highlighted when citations

are related to the gender: a significant concentration of women, especially in the first author positions, with citations >50, was found.

The analysis of the gender distribution reported in this study takes into consideration only indexed research products (articles published in peer-reviewed journals and conference proceedings) reported in the Scopus database. Moreover, it is representative of just one relative recent field of material science, so further gender-based bibliometric researches should be carried out to have a broader scenario for the material science sector. Results from this specific study can be used as the basis for future studies to bridge the gender gap and may contribute to enhancing the sensitivity toward gender issues. Finally, a continuous increase in the participation of female researchers is constantly registered in national and international conferences on AAMs and more in general in the construction material sector, thus showing an encouraging signal for narrowing the still existing gender gap.

## DATA AVAILABILITY STATEMENT

All datasets presented in this study are included in the article.

## AUTHOR CONTRIBUTIONS

MB conceptualized the topic of the study. GM elaborated the statistical data. GM, SM, and MB drafted the manuscript. All authors contributed to the article and approved the submitted version.

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**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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