



## Feature article

# Mapping of metal-organic frameworks publications: A bibliometric analysis

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## ABSTRACT

A bibliometric analysis based on the Science Citation Index Expanded from Web of Science was studied for research activities of the global metal-organic frameworks (MOFs) from 1995 to 2014. Study emphases included document types, languages, performance of publication covering annual outputs, journals, Web of Science categories, countries, and institutions. Six publication indicators including total, independent, collaborative, first authored, and corresponding authored, and single authored publications were used to evaluate publications of countries. China took a leading position of 75 countries while articles published by the USA had higher impact. An indicator SIN, a proportion of single institution articles:internationally collaborative articles:nationally collaborative articles (S:I:N) was applied to compare and describe institutions' publication characteristics. Based on number of citations since papers published to the end of the last year, citations per publication and h-index for highly cited articles were compared. In addition, Yaghi's group published the first article in the MOFs field and they contributed eight of the top ten leading articles in 2014.

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## Contents

1. Introduction . . . . .	174
2. Methodology . . . . .	175
3. Performance of publication . . . . .	175
3.1. Document type and language of publication . . . . .	175
3.2. Publication outputs . . . . .	176
3.3. Web of science categories and journals . . . . .	176
3.4. Country and institution . . . . .	176
3.5. Leading articles in 2014 . . . . .	178
4. Conclusions . . . . .	180
References . . . . .	181

## 1. Introduction

In 1995, Yaghi and co-workers in Arizona State University firstly named and published metal-organic frameworks (MOFs) in Web of Science [1,2]. MOFs are an identified class of porous polymeric material, consisting of metal ions linked together by organic bridging ligands, and are a development on the interface between molecular

coordination chemistry and materials science [3]. Open metal-organic frameworks are widely regarded as promising materials for shape-selective catalysis [4], size-selective catalysis [5], adsorption based gas [6], capture of heavy metal ions [7], gas storage [8,9], drug delivery [10], and molecular recognition [11]. Furthermore, two isostructural coordination polymers with novel anionic metal-organic frameworks were synthesized under microwave conditions using an ionic liquid EMIm-Br as solvent and template [12].

In material science related fields, Spanish authors reported a series of bibliometric studies for countries, for example Latin American, Spanish, Portuguese [13]; journals [14]; and materials and ceramics subject

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category [15]. More bibliometric studies were focused on nanoscience and nanotechnology [16,17]. The bibliometric analysis of highly cited articles in materials science was also presented in recent year [18]. In order to analyze the publication impact in a field, Ho and co-workers presented citation indicators such as the total number of citations of a paper in its publication year [19], the number of citation of a paper in the last year only [20], total citations from publication to the end of last year [21], and total citations per year [20]. Impact of an article [22] or a review paper [19] might not be always high. Most of the top articles did not have a high ranking of the citations of an article in its publication year [23]. A decreasing trend after about two years can be found in the top-10-most-cited reviews in their publication year [19]. In recent years, an indicator with two parameters, publication quantity and the characteristics of contribution to articles, was also presented [24] and applied to the highly cited articles in materials science [18].

Metal-organic frameworks related publications during the past two decades was analyzed to provide a basis for a better understanding of the global research situation, establishing medium and long term strategies of this field. The analyzed aspects covered not only the quantitative description of publications: annual outputs, mainstream journals, Web of Science categories, and leading countries, and institutions, but also the impact analyses using total citations and citations in recent year of publications.

## 2. Methodology

Data were obtained from the online version of Science Citation Index Expanded (SCI-EXPANDED) databases of the Thomson Reuters' Web of Science Core Collection. According to Journal Citation Reports (JCR) of 2014, it indexes 8618 journals with citation references across 176 Web of Science categories in science edition. "Metal-organic frameworks", "metal-organic framework", "porous coordination networks", "porous coordination network", "porous coordination polymers", and "porous coordination polymer" [25] were searched in terms of topic within the publication year limitation from 1900 to 2014. In total, 17,312 publications met the selection criteria. Another filter, the "front page", meant only the articles with the searching keywords in their front page including article title, abstract and author keywords were preserved [22]. *KeyWords Plus* supplied additional search terms extracted from the titles of articles cited by authors in their bibliographies and footnotes in the ISI (now Thomson Reuters, New York) database, and substantially augmented title-word and author-keyword indexing [26]. The articles that can only be searched out by *KeyWords Plus* were excluded. Finally, 9083 documents were regarded as the metal-organic frameworks (MOFs) publications. Downloaded information included names of authors, contact address, paper title, year of publication, document type, Web of Science categories of the article, names of journals publishing the articles, and citations in each year for each article. The records were downloaded into spreadsheet software, and additional coding was manually performed for the number of authors, country of origin of the collaborators, and impact factors of the publishing journals using Microsoft Excel 2010 [27]. Impact factors ( $IF_{2014}$ ) were taken from the JCR published in 2014.

In the SCI-EXPANDED database, the corresponding author was designated as the "reprint" author; this study instead used the term "corresponding author" [20]. In a single author article where authorship was unspecified, the single author was both first author and corresponding author [20]. Similarly, for a single institution article, the institution was classified as the first author's institution and the corresponding author's institution [28]. Articles originating from England, Scotland, Northern Ireland, and Wales were reclassified as being from the United Kingdom (UK). Articles from Hong Kong were included under the heading of China. Contributions of different institutions and countries were estimated by the affiliation of at least one author to the publications. Collaboration type was determined by the addresses of the authors [29], where the term "single country article" was assigned if the

researchers' addresses were from the same country. The term "internationally collaborative article" was designated to those articles that were coauthored by researchers from multiple countries. The term "single institution article" was assigned if the researchers' addresses were from the same institution. The term "inter-institutionally collaborative article" was assigned if authors were from different institutions [27].

## 3. Performance of publication

### 3.1. Document type and language of publication

The distribution of document types at the Web of Science has been analyzed in numerous research topics [30,31]. In recent years, Ho and co-workers presented idea of  $TC_{\text{year}}$  that is number of citations since papers published to the end of the last year [18,21,28,32]. This indicator makes total citations to be a constant as a scientific result which can be repeated and checked. In addition, citations per publication ( $CPP = TC_{2014} / TP$ ) can be also a scientific result. Table 1 shows 11 document types and their total number of publications ( $TP$ ),  $TC_{2014}$ , and  $CPP$ . As expected in science and engineering fields, journal article was the most frequently used document type [33,34] with 7937 articles, accounting for 87% of the total productions, followed by meeting abstracts (646; 7.1%) and reviews (412; 4.5%). The document type of note held the highest  $CPP$  of 603.

It was reported that a high percentage of non-article publications can be found in beginning period of a new research issue [30]. In metal-organic framework field, Yaghi and co-workers presented not only the first note "Hydrothermal synthesis of a metal-organic framework containing large rectangular channels" [1] published in *Journal of the American Chemical Society* ( $IF_{2014} = 12.113$ ) with  $TC_{2014}$  of 603 but also the first article "Selective binding and removal of guests in a microporous metal-organic framework" [2] published in *Nature* ( $IF_{2014} = 41.456$ ) with  $TC_{2014}$  of 969 in SCI-EXPANDED. Yaghi and Li [1] concluded that hydrothermal synthesis is a viable route to accessing zeolite-like materials in crystalline form and having components that are not generally observed otherwise. Articles were the dominant document type but with the 6th ranking of  $CPP$  (31). The following document type was meeting abstracts with four citations only. Furthermore, reviews had a high  $CPP$  of 172 which is 5.6 times of document type of articles. Only the document type of article was further analyzed, since they represented the majority of document types that also included whole research ideas and results [35].

Ninety-nine percent of 7840 articles were published in English. Several other languages also appeared: Chinese (85), German (4), Japanese (3), and one for each of Croatian, French, Portuguese, Slovak, and Turkish respectively. Such high percentage (99%) of English articles was also reported in wetland research [36]. Thirsty-3% of 97 non-English articles in MOFs field had no citations ( $TC_{2014} = 0$ ), 19% articles had one citation ( $TC_{2014} = 1$ ), and 10% articles had two citations ( $TC_{2014} = 2$ ) while 14%, 7.2%, and 5.4% of 7840 English articles had  $TC_{2014} = 0$ ,  $TC_{2014} = 1$ , and

**Table 1**  
Document types of metal-organic frameworks publications in SCI-EXPANDED.

Document type	TP	%	$TC_{2014}$	CPP
Article	7937	87	245,334	31
Meeting abstract	646	7.1	4	0.0062
Review	412	4.5	70,892	172
Proceedings paper	102	1.1	3367	33
Editorial material	36	0.40	1791	50
Correction	26	0.29	42	1.6
Book chapter	21	0.23	446	21
News item	21	0.23	219	10
Letter	3	0.033	291	97
Note	1	0.011	603	603
Reprint	1	0.011	1	1.0

*TP*: total publications;  $TC_{2014}$ : total number of times cited since the paper was published to the end of 2014; *CPP*: citations per publication ( $TC_{2014}/TP$ ).

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