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Bibliometric analysis of global research trends on microbial fuel cells using Scopus database

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ABSTRACT

The rising demand for sustainable energy and the availability of abundant wastes have stimulated research efforts around the world. As a newly emerging energy-based technology, microbial fuel cell (MFC) has received a significant attention due to its broad range of applications. Therefore, understanding the topics of interest and broadening collaboration networks are necessary to advance the research development towards integrated efforts. In this bibliometric study, our aim was to evaluate the global research trends in MFC area based on publication outputs, co-authorships among authors and affiliated countries, and co-occurrences of author keywords. Using the Scopus database, a total of 4126 journal articles published between 1962–2017 were retrieved. Results have shown that since 2008, the number of publications increased by 100 articles every two years, resulting in the steady increase in the cumulative total publications until present. About 60% of the global total publications were contributed by researchers from China and USA, leading the other 70 countries/territories. Also, among the most productive university from each of the 15 leading countries, four were amongst the world's top 100 universities. In conclusion, recent progress in MFC research includes the following (but not limited to) (i) electrode materials incorporated nanotechnology, ceramic, and biochar; (ii) mathematical modeling (e.g. artificial neural network); and (iii) economic assessment and life cycle analysis.

1. Introduction

Depletion of fossil fuels, abundance of wastes, impacts of climate change, and exponential growth of human populations are among some of the factors that lead the global community to search for alternatives to fulfill the global energy demand [1]. Microbial fuel cell (MFC) technology has been identified as one of the promising solutions for a sustainable energy [2], with a bright prospect for future implementation [3]. MFC is a device that exploits microbial catabolic activities to generate electricity from carbon source under anaerobic conditions. Several advantages, which MFC offers over other energy technologies using organic matter, include the flexible operating temperatures, in-situ energy conversion, and potential application in remote locations lacking electrical infrastructures [4]. Previous studies suggested that applications of MFC included but not limited to electricity generation, wastewater treatment, bioremediation/biodegradation, and biosensor [2,5].

Although there has been a growing interest in MFC technology, very few studies were dedicated to measuring and analyzing scientific publications from a global perspective. Juan et al. [5] presented research trends on bioelectrochemical systems (BES) for a period of 24 years since 1991, where MFC was a part of discussion besides enzymatic fuel cell, microbial electrolysis cell, microbial desalination cell, and microbial solar cell. On the other hand, Mercuri et al. [1] had focused specifically on MFC, however, it was limited to microbiology and marine freshwater biology areas. Additionally, both studies used Web of Science (WoS) as a source of data mining.

Despite the fact that WoS and Scopus databases have a high association i.e. overlap in journal indexing, they also index different journals [6,7]. Scopus is recognized as the largest abstract and citation database of peer-reviewed literature covering a wide range of subjects. Thus, using Scopus is an attempt to cover more topics which may not be available in WoS and may not have discussed by Juan et al. [5] and Mercuri et al. [1].

Abbreviations: MFC, microbial fuel cell; AGR, annual growth rate; SCP, single-country publication; MCP, multi-country publication; TP, total publications; TC, total citations; TPc, total publication of a given country; TPi, total publication of a given academic institution.

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In this paper, our objectives were as follows: i) to analyze temporal distribution patterns of MFC journal articles; ii) to show contributions of prolific authors, leading countries and the most productive academic institutions; (iii) to highlight common terminology and research topics; (iv) to determine domination of countries based on major applications; and (v) to provide insight into potential collaboration and future directions. This paper will be beneficial for researchers, policy makers, and individuals to understand the research trends in MFC and to discover the potential and opportunities for future research.

2. Methods

Bibliometric analysis study is a mechanistic approach to understand the global research trends in a specific area based on the outputs of the academic literature database. This kind of approach distinguishes a bibliometric analysis paper from a review paper which primarily intended to discuss the latest progress, challenges, and future directions of a certain topic.

2.1. Data source and search strategy

Data mining was conducted within February 9 and 15, 2018 using Scopus database. The central theme in this study was research articles containing "microbial* fuel* cell*" in the title and abstract. The oldest publication dates to 1962 and the more recent ones are from 2017. The query string used for the search was: (TITLE-ABS ("microbial* fuel* cell*")) AND DOCTYPE (ar) AND PUBYEAR > 1959 AND PUBYEAR < 2018 AND (LIMIT-TO (SRCTYPE, "j")). This query string resulted in 4246 documents. To ensure no review articles were in our analysis, additional phrases were added in the query string which resulted in 148 articles being potentially irrelevant to our study. These articles contained terms such as review, recent, progress, critical, revisit, advance, highlight, in the title and abstract. After screening them by reading abstracts and full-texts, we identified 84 of them were review articles. EID, a Scopus unique article identifier, of these review articles were noted and added in the next search string (so that they would not appear in the next search results).

It is noteworthy that the best method to obtain the most accurate data on an author's output is to use its author ID (Scopus field code: AU-ID). An author profile is a collection of all the name variants placed in one single profile, e.g., our exported data had the last name Ieropoulos twice, however, with different initials which were Ieropoulos, I. (68 articles) and Ieropoulos, I.A. (17 articles).

Information for single-country publication (SCP) were retrieved by limiting the search result to a specific country using a field code AFFILCOUNTRY.

The search results of the central theme were analyzed based on year, source, author, affiliation, country/territory, subject area, and document type. Bibliometric indicators such as total publications, total citations, CiteScore, and h-index were used for ranking purposes.

In addition, we also created a sub-theme to explore the output trends in MFC major uses. The MFC major applications included in this study were i) electricity generation; ii) wastewater treatment; iii) biodegradation/bioremediation; and iv) biosensor. The search string for each application was run separately. By using previous search string, specific terms were added to it depending on the type of applications, for e.g. (*electricity OR "power generation") or ("waste*water treatment") or (*remediat* OR *degradat*) or (*sensor). The search results by sub-theme were analyzed based on publication output per year.

There are chances that one application may overlap with other application(s). For example, an article on biosensor application is likely related as well to the electricity generation. However, to minimize the overlap between wastewater treatment and biodegradation/bioremediation, we excluded "wastewater treatment" from the biodegradation/bioremediation search. By excluding "wastewater treatment", the search on biodegradation/bioremediation was made to focus on contaminated soil, sediment, solid waste, etc.

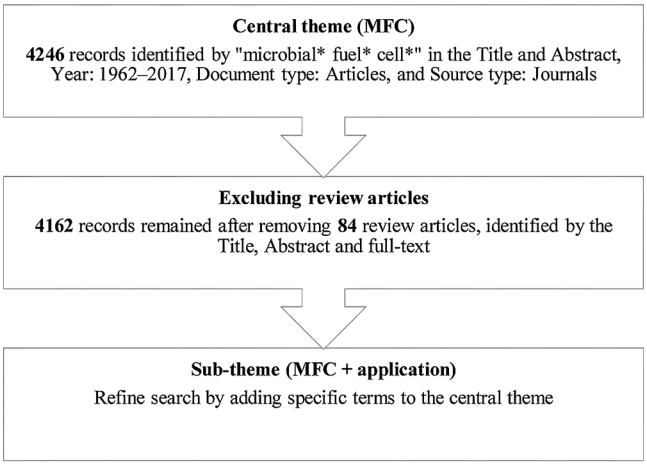

Fig. 1. Flowchart of gathering data of publications for central and sub-themes.

The process of record collection and study elimination is summarized in Fig. 1. The details on search strings used in Scopus are provided in Table S1 (Supplementary Material).

2.2. Bibliometric maps

Citation, bibliographical, and author keywords information of 4126 articles were exported to VOSviewer (version 1.6.7, Centre for Science and Technology Studies, Leiden University, The Netherlands), a software tool for constructing and visualizing bibliometric maps. Maps created using VOSviewer include items. In this study, the items are the objects of interest, namely the countries or author keywords. Between any pair of items there can be a link—connection or relation between two items. Each link has a strength, represented by a positive numerical value. The higher this value, the stronger the link.

In the case of co-authorship analysis, the link strength between countries indicates the number of publications that two affiliated countries have co-authored, whereas the total link strength indicates the total strength of the co-authorship links of a given country with other countries. Similarly, in the case of co-occurrence analysis, the link strength between author keywords indicates the number of publications in which two keywords occur together. Details on the features of VOSviewer can be found in the user manual [8].

2.2.1. Analysis of co-authorship

In the analysis of co-authorship, we included all 72 countries affiliated with 6783 authors. The affiliated countries/territories were clustered into 5 continents: Africa, America, Asia, Europe and Oceania.

2.2.2. Analysis of co-occurrence

Analysis of co-occurrence of author keywords (not Scopus indexed keyword) involved 6059 keywords from 3464 articles. The remaining 698 articles were excluded due to the lack of author keywords information available from 142 journals. Prior to importing the list of author keywords to VOSviewer, synonymic single words and congeneric phrases were analyzed. For example, plant micro-