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Bibliometric analysis of research trends on solid waste reuse and recycling during 1992–2016

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ABSTRACT

A bibliometric analysis of solid waste reuse and recycling was performed to trace the research trends and hotspots based on the literature in Science Citation Index (SCI) database from 1992 to 2016. Research trends were explored in each 5-year period, and the social network analysis was conducted to analyze collaborations among authors and co-occurrence of keywords. Results showed a rapid increase in publication outputs with wide international collaboration. Developing countries contributed the significant growth during 2007–2016. Comprehensive journals, such as *Waste Management* and *Resources, Conservation & Recycling*, tend to be much influential. Based on analyses of dominant categories, high-cited papers and co-authorship network, hot issues and research trends could be summarized as follows: 1) e-waste and biodiesel production from waste oil began to get wide attention since 2002 and 2007. 2) A large gap was observed between developed and developing countries in C&D waste and organic fraction of municipal solid waste. 3) Sustainability, industrial ecology and informal recycling became attractive hotspots of solid waste management in developing countries since the period of 2002–2006. In summary, developing countries entered a rapid development period in the field of solid waste reuse and recycling. Perspectives of sustainability and industrial ecology, integration of informal recycling into formal system, and reinforcement of composting, anaerobic digestion and C&D recycling could be feasible options for integrated waste management system in developing countries.

1. Introduction

Advancement in material science and rapid development of industrialization and urbanization have led to huge quantity of solid waste (Korai et al., 2017; Tansel, 2016). According to ‘Global waste management outlook’, reported by United Nations Environment Programme (UNEP) and the International Solid Waste Association, the global generation of ‘urban’ wastes was estimated at around 7–10 billion tons per annum, and the amount per capita has risen distinctly over the last 50 years (Wilson et al., 2015). The ‘urban’ wastes mainly include municipal solid waste (MSW), commercial and industrial (C&I) waste, and construction and demolition (C&D) waste. The compositions of MSW include textiles, metals, glass, plastics, paper and organic materials. C&D waste often represents the largest proportion of total waste generated, which accounts for 34% of the urban waste generated within OECD countries, and mainly include concrete, masonry, wood and asphalt (Metin et al., 2003; Moh and Manaf, 2017). Adverse effects of solid waste mismanagement on environment and public health, have promoted the development of technologies for solid waste reuse and

recycling (Brereton, 1996; Giusti, 2009; Hamer, 2003). Among various disposal technologies, incineration is the most common disposal option to recover energy and minimize the volume of solid waste. However, it is an option of lower conversion efficiency and higher cost compared with recycling (Morris, 1996). Composting is another attractive disposal method, which has been used to recycle organic matter back into the soil to improve soil structure and fertility for centuries (Imbeah, 1998). Moreover, some novel disposal and management technologies, such as fermentation, and thermochemical processes, developed rapidly in recent decades (Almeida, 2016; Walker et al., 2009).

Bibliometric analysis is a useful method to identify research trends and hot issues based on historic publications information (Bi, 2013). It is also used to evaluate research performance of institutions, researchers and journals, as well as the research fields (Wang et al., 2010). In recent years, some work related to solid waste has been done based on bibliometric analysis. H. Fu (Fu et al., 2010), H. Ma (Ma et al., 2011), and L. Yang (Yang et al., 2013), have evaluated research trends of solid waste based on SCI-E database during 1993–2008 1991–2010 and 1997–2011, respectively. Results showed that (1) recycling was one

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of the most concerned and common methods for solving solid waste problems; (2) Research between developing and developed countries presented a large gap; and (3) China yield a large number of publications but possessed a low h-index.

Therefore, we analyze related studies from 1992 to 2016 to explore (1) whether changes occurred in the last 5 years compared with the research before 2012, (2) leading countries and collaborations in both international and domestic, and (3) the research status, development trends and hot issues in the field of solid waste reuse and recycling. In this study, we provide an updated review of this field during 1992–2016, and conduct a comparison research with studies in each 5-year period based on conventional bibliometric methods and literature analysis tools. The co-authorship network analysis and co-occurrence of author keywords are performed for further understanding of the global research status and development trends. Moreover, the annual outputs, dominant categories, most influential journals, and leading countries and institutions are analyzed.

2. Methodology and data

2.1. Data

The Web of Science (WoS), developed by Thomson Reuters Scientific, is one of the most widely used database in such studies. It provides more consistent and standardized records and better graphics in citation analysis compared to other databases, and allows to download full citation records into a “.txt” file compatible with most of literature analysis tools, such as Bibexcel (Falagas et al., 2008; Newell and Cousins, 2015). Information on scientific was searched in the database of Science Citation Index Expanded (SCI-E), Social Sciences Citation Index (SSCI), Conference Proceedings Citation Index- Science (CPCI-S) and Conference Proceedings Citation Index- Social Science & Humanities (CPCI-SSH), which are all sub databases in Web of Science. The results were retrieved on January 12, 2017 with the search equation of “TS = ((solid waste*) AND (reuse or recycling or recycle))”, which means records of publications containing terms of solid waste (or solid wastes) and reuse or recycle (or recycling) in the abstract, title, and/or keywords of a record. After eliminating records unrelated to the topic manually, mainly about wastewater treatment, a total of 6289 publications met the selection criteria. Data on author names, document type, language, publication years, addresses, subject categories, journals, title, author keywords, Keywords Plus, funding agency, and abstract has been collected for analyses.

2.2. Methodology

Social network analysis was widely employed to visualize and analyze the relationships between various nodes in bibliometric related studies, such as co-occurrence of keywords, academic collaborations among authors, institutions, and countries. The weighted undirected network model within the Netdraw was used to conduct the co-authorship and co-word network analysis and visualization, based on collaborations among researchers and co-occurrence of keywords in the same published papers. The size of nodes and weight of edges are proportional to the number of published articles and the times the authors have published together, respectively. The nodes are colored based on the modularity class they belong (Marinoui et al., 2015). Co-word network and high-cited paper analyses were performed to trace research trends and possible hotspots.

The impact factor (IF) is one of the most popular indicators to measure the quality of research papers, the researchers who wrote those papers, and even the institutions they work in (Amin and Mabe, 2003). However, it only reflects the average citations per annum of articles published in last two years, and could not represent the citations of specific papers and identify the effect of highly cited articles. The h-index, defined by the h of N_p papers having at least h citations each and

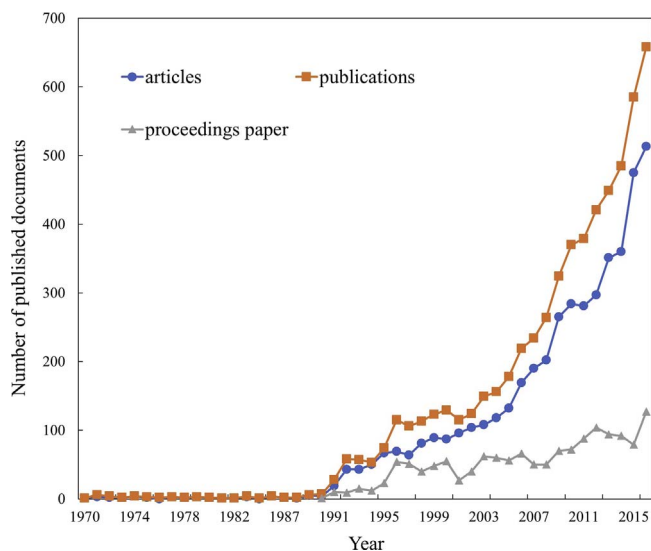


Fig. 1. Annual number of published documents in 1970–2016.

the other (N_p -h) papers have $\leq h$ citations each, can measure both the quantity and citations of publications, where N_p is the number of papers published over n years (Hirsch, 2005, 2010). Therefore, these two indicators were used to evaluate the quality and scientific research impacts of journals and countries. The contribution of different countries and institutions to the publications was estimated based on the affiliation of at least one author. We divided articles into “single institution article”, “single country article”, and “international collaborative article”. The “single country article” was assigned if the authors were affiliated to different institutions within the same country. Articles that originated from England, Scotland, Northern Ireland, and Wales were grouped as the United Kingdom (UK).

3. Results and discussion

3.1. General trends

The annual number of publications from 1970 to 2016 was presented in Fig. 1. Documents published during 1992–2016 will be analyzed emphatically owing to less convincing of insufficient data before 1991, which less than 10 records per year. As shown in Table 1, the number of publications related to solid waste reuse and recycling increased obviously, from 58 in 1992 to 658 in 2016, may be result of financial support from various funding agencies, which increased from 3.7% in 2006 to 58.2% in 2016. Meanwhile, the remarkable increase of international collaborative publications and average number of authors per document illustrated that the collaborations among authors increased continuously, especially the international collaboration. Moreover, the articles were the dominant type, which accounted for approximately 76.4% (4539) of the total number, and were used for further analysis together with proceedings papers (1444, 24.31%). English (5786, 97.40%) was the mainstream language, followed by Portuguese (61), German (28), Spanish (27) and Japanese (21).

3.2. Distribution of journals

The 5609 articles/proceedings papers were published in 1402 journals or conference. The top 10 productive journals, shown in Table 2, published approximately 26.8% papers of the total number. *Waste Management*, which incorporated with *Advances in Environmental Research* in 2005, published the most articles (386, 6.88%) with the highest h-index of 43. *Resources, Conservation & Recycling (RCR)* ranked second (261, 4.65%) in both number of articles and h-index of 39. *Waste Management*, *RCR* and *Waste Management & Research* are all

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