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A bibliometric analysis of the Journal of Membrane Science (1976-2010)

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A bibliometric analysis of the *Journal of Membrane Science* (1976-2010)

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Abstract

Purpose – This study aims to examine publication characteristics and development of a science journal *Journal of Membrane Science* (*JMS*) with 35 years' history by bibliometric indicators.

Design/methodology/approach – A bibliometric approach was used to identify its document types, impact factor, publication outputs, most cited articles and large contributing countries/territories and institutions. The main indicators included impact factor, CPP (citations per publication), TC2010 (number of citations from one paper's publication to the end of 2010), C2010 (number of citations in the year of 2010), number of total articles, "single country articles" and "single institution articles", "internationally collaborative articles" and "inter-institutionally collaborative articles", "first author articles" and "corresponding author articles". The annual citations of most cited articles were displayed in a table list.

Findings – The two-year citation window used by impact factor is not fair for a journal which had its peak annual citations in the third or more years. *JMS* would get a better citation performance if impact factor can be calculated for three or four years. Impact factor is affected by the size of its subject categories. *JMS* showed higher impact factor rankings in both chemical engineering and polymer science category in the early twenty-first century. Furthermore, the G8 (Canada, France, Germany, Italy, Japan, Russia, the UK and the USA) contributed more than a half of the total, with higher CPP. National University of Singapore, University of Twente and Chinese Academy of Sciences were the main contributing institutions. The citation life cycles revealed the impact history of most cited articles.

Originality/value – A bibliometric analysis has been carried out to analyze the characteristics of a journal with 35 years' history. Some improved indicators including TC2010, C2010, TP, SP, CP, FP and RP have been used for the evaluation. This study provides an evidence from *JMS* to discuss the feasibility and limitations of impact factor.

Keywords Data analysis, Information resources management

Paper type Research paper

1. Introduction

The *Journal of Membrane Science* (*JMS*) was launched in 1976 by Harry Lonsdale, the founding editor, with the original purpose to "recognize and draw together a new field – one that might be called 'membranology', [–] and deal with the science and technology of membrane processes" (Koros, 2006). In this study, the bibliometric method was used to get an overview of *JMS* over the past 35 years. Bibliometric analysis, based on statistical data about publications, citations and other related indicators, has been widely used to reveal objective performance and development of scientific journals, for example the

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American Journal of Roentgenology (Elster and Chen, 1994; Chen *et al.*, 2003), *Physics* (Wagner-Dobler and Berg, 1999), the *American Journal of Veterinary Research* (Crawley-Low, 2006), *Zoo Biology* (Anderson *et al.*, 2008), *Uspekhi Khimii* (Zibareva *et al.*, 2008), *Intelligence* (Wicherts, 2009), *Pain* (Dubner, 2009), *Water Research* (Wang *et al.*, 2010) and *Physical Therapy* (Coronado *et al.*, 2011). The number of publications by document types (Zibareva *et al.*, 2008; Wang *et al.*, 2010; Coronado *et al.*, 2011) and publication years (Wang *et al.*, 2010; Coronado *et al.*, 2011) are often used to provide basic information about a journal. The impact factor (IF), created in the early 1960s (Garfield, 1999), has become a staple in many types of analyses of a journal's scientific impact (Garfield, 1997). Another commonly used term to feature a journal is citation classics (Garfield, 1971; Garfield, 1984; Wicherts, 2009). As one of the first studies published, Garfield compiled a list of the 50 most cited articles (Garfield, 1971). Lists and features of citation classics have been focused on individual journals in many research studies (Garfield, 1984; Picknett and Davis, 1999; Zibareva *et al.*, 2008; Wicherts, 2009; Coronado *et al.*, 2011). Meanwhile, citations per publication (CPP), which could provide a "monitoring device" for management and science policy (Moed *et al.*, 1985), has been applied in various studies (Seng and Willett, 1995; Katz and Hicks, 1997; Huang *et al.*, 2008). Furthermore, the internationalization of journals was also an important concern to identify centres of intellectual activity (Elster and Chen, 1994; Chen *et al.*, 2003). Indicators related to the total number of articles, independent and collaborative articles, that have been applied to evaluate the research performance of countries/territories and institutions (Chiu and Ho, 2005; Chiu and Ho, 2007; Wang *et al.*, 2010; Ho *et al.*, 2010). Recently, indicators related to corresponding author and first author were also used to bulk out the performance of countries/territories and institutions (Wang *et al.*, 2010, 2011; Ho *et al.*, 2010).

This study presents a comprehensive analysis of a high-impact science journal with various bibliometric indicators. The main body of this study is divided into five parts and identifies the characteristics of the *JMS*, covering document types, trends in production, national and institutional contributors, citation patterns for IF and the most cited papers. First, the overall scientific performance of the used document types' distribution is illustrated. Then, trends of number of total articles and highly cited articles are presented to examine the productivity of high-impact articles. The third section deals with major national contributors and international players of the investigated journal. The fourth section reveals citation patterns, with a major focus on annual CPP and rankings of the IF in different categories. Finally, the most cited papers of the journal are identified as a statement of discipline emphases.

2. Methodology

Documents used in this study were derived from the Science Citation Index Expanded (SCI-Expanded) database of the Web of Science database, from Thomson Reuters. The keyword phrase "*Journal of Membrane Science*" was searched as the publication name based on SCI-Expanded. A total of 9,913 documents from 1976 to 2010 were found and downloaded for analysis.

The bibliometric indicators acronyms and terms used in this study are given in Table I. The analysis was conducted on various indicators, including citation-related indicators (IF, CPP, number of citations from one paper's publication to the end of 2010 [TC2010] and number of citations in the year of 2010 [C2010]) and quantity-related

Acronym	Description
SCI-Expanded	Science Citation Index Expanded
JCR	*Journal Citation Reports*
IF	Impact factor from *Journal Citation Reports*
JMS	*Journal of Membrane Science*
CPP	Citations per publication
PCPP	Peak citations per publication
TC2010	Number of citations the analysed publication received from its publication to the end of 2010
C2010	Number of citations the analysed publication received in 2010
TP	Number of total articles
SP	Number of "single country articles" or "single institution articles"
CP	Number of "internationally collaborative articles" or "inter-institutionally collaborative articles"
FP	Number of "first author articles"
RP	Number of "corresponding author articles"

Table I.
Introduction of the acronyms used in subsequent analysis

indicators (TP, SP, CP, FP and RP). TC2010 and C2010 were developed by Chuang *et al.* (2011) to assess the citations of articles. The citation index feature of Web of Science was updated as time went on. By comparison, TC2010 was an invariable parameter to ensure repeatability to provide more scientific and accurate information. One article's C2010 is calculated to identify the latest and the most influential research. Collaboration type of country/territory and institution was determined by the addresses of the authors. The articles were classified by the following four types for country/territory and institution:

(1) The term "single country article" was assigned if the researchers' addresses were from the same country and the term "single institution article" was assigned if the researchers' addresses were from the same institution.

(2) The term "internationally collaborative article" was designated for those articles that were co-authored by researchers from multiple countries and the term "inter-institutionally collaborative article" was assigned if authors were from different institutions; note that the term "inter-institutionally collaborative articles" includes "internationally collaborative articles".

(3) The term "first author article" was assigned to the articles for the analysed country/territory or institution, if the address of the first author was listed from the analysed item. For example, if the first author of an article listed the USA as his or her address, the article was assigned to one "first author article" of the USA.

(4) The term "corresponding author article" was assigned to the articles for the analysed country/territory or institution, if the address of the corresponding author was listed from the analysed item.

All document information was downloaded from the SCI-Expanded database into a Microsoft Excel 2010 sheet. All analyses were manually calculated by self-designed algorithms and built-in functions by Microsoft Excel 2010 using the indicators in Table I.

3. Results

3.1 Document types

There were 9,913 papers published in *JMS* from 1976 to 2010 (Table II). These publications included 11 document types. The information on document types was obtained from Web of Science and, therefore, the analysed document types are the same as those used in Web of Science. The document type of review held the highest CPP of 84. Articles (9,192) were the dominant document type comprising 93 per cent of the total productions with the third ranking of CPP (19). This suggests, on average, one article in *JMS* receives 19 citations. The next document type was proceedings paper (267; 2.7 per cent) with the second ranking of CPP (26), followed by note (105; 1.1 per cent). Review (91; 0.92 per cent) had the highest CPP among these 11 document types. As articles were the dominant type of document, only the articles were used for further analysis covering publication outputs, contributors of countries/territories and institutions and citation life cycles of the most cited articles.

3.2 Trends of number of articles and highly cited articles

The number of annual articles and annual highly cited articles were used to discover the development of production. Of the 9,192 articles, the number of articles increased nearly 34-fold from 21 in 1976 to 709 in 2010, despite slight fluctuations (Figure 1). It is noticeable that the years 2006 and 2008 published the most annual articles. The most frequently cited papers with significant impact have been investigated in recent bibliometric literature (Paladugu *et al.*, 2002; Baltussen and Kindler, 2004; Hannerz, 2010; Ponce and Lozano, 2010; Shadgan *et al.*, 2010). Therefore, annual highly cited articles (TC2010 > 50) are identified and shown as a percentage with the denominator of the total annual articles in Figure 1. There were 731 articles cited more than 50 times till the end of 2010, accounting for 8.0 per cent of the total articles. Among these 731 articles, 573 (73 per cent) were issued during the period of 1991-2004. The most productive years of highly cited articles were 1999 and 2001 with 48 articles. The percentage of top articles ranged from 32 per cent in 1977 to 0.13 per cent in 2008. The year with the greatest percentage of highly cited articles was 1977 when 32 per cent (7/22) of articles were cited more than 50 times, followed by 1981 with the percentage of 22 (8/36), and 1984 with the percentage of 20 (20/99). The percentage fell from 15 in 2001 to 0.13 in 2008, and no articles were published in 2009 and 2010. The percentage of highly cited articles

Document types	TP	(%)	TC2010	CPP
Article	9,192	93	174,305	19
Proceedings paper	267	2.7	7,000	26
Note	105	1.1	1,561	15
Editorial material	98	1.0	43	0.44
Review	91	0.92	7,612	84
Letter	61	0.62	74	1.2
Correction	43	0.43	36	0.84
Addition correction	22	0.22	4	0.18
Reprint	13	0.13	175	13
Biographical item	12	0.12	0	0
Item about an individual	9	0.091	0	0

Table II. Document types of the *Journal of Membrane Science* (1976-2010)

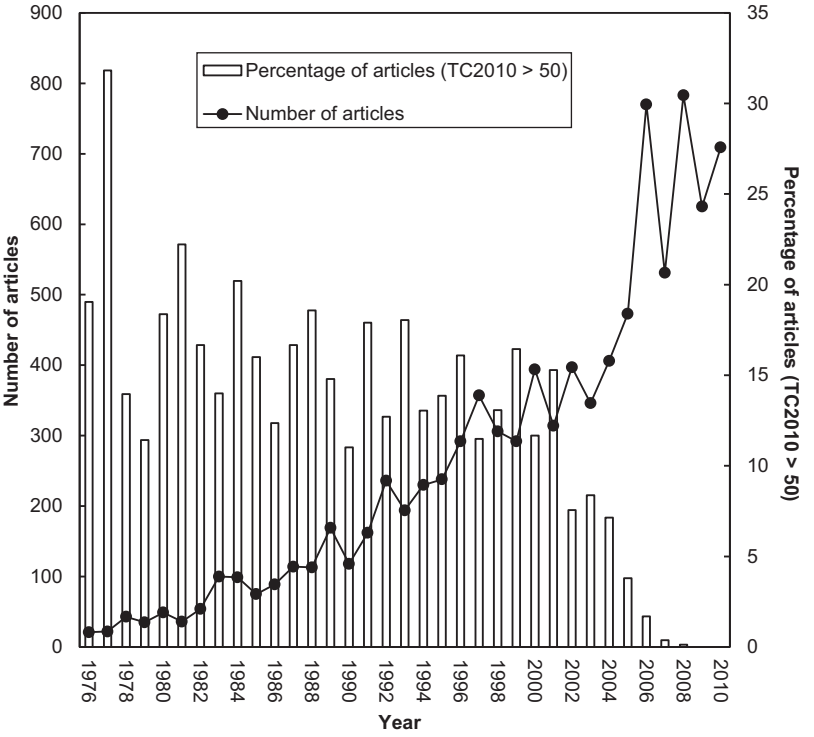

Figure 1.
Trend of number of articles and percentage of highly cited articles (TC2010 > 50)

in earlier years was higher than that in recent years, while the number of highly cited articles in recent years was much higher than that in older years. Moreover, 966 articles (9.7 per cent of the total articles) received no citations from their publication to 2010. Fifty-three per cent of the 966 articles were published in 2010.

3.3 Characteristics of countries/territories and institutions

JMS was contributed to by various countries/territories and institutions. A simple pre-treatment for countries/territories was interpreted to provide directions for readers. Articles originating from England, Scotland, Northern Ireland and Wales were re-classified as being from the UK. Articles from Hong Kong were not included in the ones from China, but as a territory. Excluding 13 articles without any author address information on Thomson Reuters's Web of Science, the remaining 9,179 articles originated from 86 countries/territories. Among those articles, 7,829 (84 per cent) were independent publications, while 1,350 (15 per cent) were internationally collaborative publications. Table III shows the characteristics of the top 20 most productive countries/territories. The top 20 countries accounted for 91 per cent of the total articles. The eight major industrialized G8 countries (Canada, France, Germany, Italy, Japan, Russia, the UK and the USA) were ranked in the top 20 list, accounting for 56 per cent of the total articles. The USA dominated in this journal, not only ranking the first in terms of TP, SP, CP, FP and RP, but also ranking first with respect to CPP (26). Although China was ranked second in TP, CP, FP and RP, it was ranked only 19th in terms of CPP of the 20

Country/territory	TP	TP R (%)	SP R (%)	CP R (%)	FP R (%)	RP R (%)	CPP
USA	2,137	1 (23)	1 (23)	1 (25)	1 (21)	1 (19)	26
China	1,035	2 (11)	3 (10)	2 (17)	2 (10)	2 (11)	12
Japan	956	3 (10)	2 (10)	6 (11)	3 (10)	3 (9.4)	19
France	674	4 (7.3)	4 (5.8)	3 (16)	4 (6.0)	4 (5.8)	19
South Korea	450	5 (4.9)	5 (4.4)	11 (7.7)	5 (4.3)	5 (4.6)	18
Canada	443	6 (4.8)	8 (3.8)	6 (11)	6 (4.0)	6 (4.1)	18
UK	411	7 (4.5)	10 (3.4)	5 (11)	8 (3.7)	8 (3.7)	20
Germany	399	8 (4.3)	11 (2.9)	4 (13)	11 (3.3)	11 (3.3)	24
India	367	9 (4.0)	6 (4.2)	18 (2.7)	7 (3.8)	9 (3.7)	13
The Netherlands	366	10 (4.0)	9 (3.7)	12 (5.9)	10 (3.6)	10 (3.6)	19
Spain	346	11 (3.8)	12 (2.8)	8 (9.3)	12 (3.2)	11 (3.3)	14
Taiwan	339	12 (3.7)	7 (3.8)	16 (2.9)	9 (3.6)	7 (3.8)	13
Singapore	290	13 (3.2)	14 (2.3)	10 (8.3)	13 (2.7)	13 (3.0)	17
Australia	278	14 (3.0)	15 (2.1)	9 (8.5)	15 (2.3)	15 (2.3)	22
Italy	243	15 (2.6)	13 (2.3)	13 (4.5)	14 (2.3)	14 (2.4)	18
Poland	131	16 (1.4)	16 (1.2)	16 (2.9)	16 (1.2)	16 (1.3)	12
Portugal	118	17 (1.3)	17 (1.0)	19 (2.7)	17 (1.2)	17 (1.2)	13
Russia	110	18 (1.2)	25 (0.69)	14 (4.1)	19 (0.83)	21 (0.80)	14
Belgium	99	19 (1.1)	21 (0.73)	15 (3.1)	20 (0.81)	18 (0.83)	18
Israel	91	20 (1.0)	18 (0.93)	30 (1.3)	18 (0.90)	19 (0.81)	17

Note: R (%): rank (share in publications)

Table III. Characteristics of the top 20 productive countries/territories

countries/territories. Japan was ranked third in TP, second in SP and sixth in CP, and had a CPP of 19. The countries in which CPP were no less than 20 were all industrialized countries: the USA (26), Germany (24), Australia (22) and the UK (20).

Of the 9,179 articles from 3,076 institutions in 86 countries, 3,477 (38 per cent) were inter-institutionally collaborative publications and 5,702 (62 per cent) were independent publications. The 5,702 (62 per cent) inter-institutionally collaborative articles included 1,350 (15 per cent) internationally collaborative articles. Three institutions in the USA; three in China; and one each in Singapore, The Netherlands, Australia and Taiwan were ranked in the top ten most productive institutions (Table IV). The National University of Singapore in Singapore was ranked first in TP, CP, FP and RP, but it was ranked sixth in SP. The University of Twente in The Netherlands was ranked second in TP, CP, FP and RP; was ranked first in SP; and had a CPP of 24. The Chinese Academy of Sciences in China was ranked third in TP, SP, CP and RP; was ranked fourth in FP; and had a CPP of 15. The institutions of the top ten institutions whose CPP were no less than 20 were the University of Texas in the USA (44), University of New South Wales in Australia (30), University of Colorado in the USA (26), University of Cincinnati in the USA (25) and University of Twente in The Netherlands (24). This phenomenon was consistent with the results of countries/territories.

3.4 Characteristics of IF

According to the *Journal Citation Reports*, in 2010, *JCR* indexed 8,005 journals with citation references across 174 scientific disciplines. IF can be calculated by the average

Institution	TP	TP R (%)	SP R (%)	CP R (%)	FP R (%)	RP R (%)	CPP
National University of Singapore, Singapore	203	1 (2.2)	6 (1.5)	1 (3.4)	1 (1.8)	1 (2.0)	19
University of Twente, The Netherlands	188	2 (2.0)	1 (1.9)	2 (2.3)	2 (1.8)	2 (1.6)	24
Chinese Academy of Sciences, China	165	3 (1.8)	3 (1.5)	3 (2.2)	4 (1.3)	3 (1.4)	15
University of Colorado, USA	143	4 (1.6)	5 (1.5)	7 (1.7)	3 (1.3)	5 (1.1)	26
University of Texas, USA	139	5 (1.5)	4 (1.5)	10 (1.5)	5 (1.3)	10 (0.73)	44
University of New South Wales, Australia	136	6 (1.5)	2 (1.6)	13 (1.3)	6 (1.2)	4 (1.2)	30
Chung Yuan Christian University, Taiwan	106	7 (1.2)	27 (0.53)	4 (2.2)	14 (0.66)	14 (0.65)	13
University of Cincinnati, USA	105	8 (1.1)	8 (1.2)	18 (1.1)	7 (0.93)	20 (0.57)	25
Tianjin University, China	94	9 (1.0)	10 (1.1)	25 (0.95)	7 (0.93)	7 (1.0)	14
Zhejiang University, China	93	10 (1.0)	9 (1.1)	28 (0.89)	7 (0.93)	6 (1.0)	10

Note: R (%): rank (share in publications)

Table IV. Characteristics of the top ten productive institutions

number of times articles from the journal published in the past two years have been cited in the *JCR* year (http://admin-apps.webofknowledge.com/JCR/help/h_impfact.htm). Figure 2 displays the IF of *JMS* by *JCR* with an overall increasing trend from 1.36 in 1977 to 3.673 in 2010. Its 2010 IF (3.673) suggests that, on average, the articles published in 2008 and 2009 in *JMS* have been cited more than three times in 2010. Each journal indexed in *JCR* is assigned to at least one subject category, indicating a general area of science (http://admin-apps.webofknowledge.com/JCR/help/h_subjinfo.htm). The citation performance varied among small or large research disciplines (Garfield, 1997) and, therefore, the rank of IF in its subject categories was also identified to lower the side effect of category size. *JMS* was listed in two Web of Science subject categories: chemical engineering and polymer science. According to the IF, the percentiles of the *JMS* ranking to total journals in the chemical engineering and the polymer science categories are shown in Figure 2. The values of chemical engineering and polymer science hovered around 5.0 per cent within a range of 2.3 per cent and 12.5 per cent within a range of 5.8 per cent, respectively, indicating a better ranking in chemical engineering. These slight fluctuations also revealed little change during the 35-year study period. The year 2006 had the highest ranking in both categories, 3/110 in chemical engineering and 5/75 in polymer science, followed by the year 2002 (6/126 and 7/74) and the year 2008 (7/116 and 8/75), respectively.

How quickly recent articles are cited is an important factor that affects IF (Garfield, 1999). To examine the history of citations, CPP by year were examined for *JMS*. The CPP increased fast after publication to 2.70 CPP in the third year, reached a maximum in the fourth year (PCPP = 2.71), then started to fall until a minimum in the 32nd year (0.453) and finally increased again (Figure 3). However, the second year (2.48) used for IF was just ranked fifth among the number of years after publication. As IF only considers citations in the two years after publication, the IF of *JMS* will be higher if it is calculated with the citation window of three or four years.

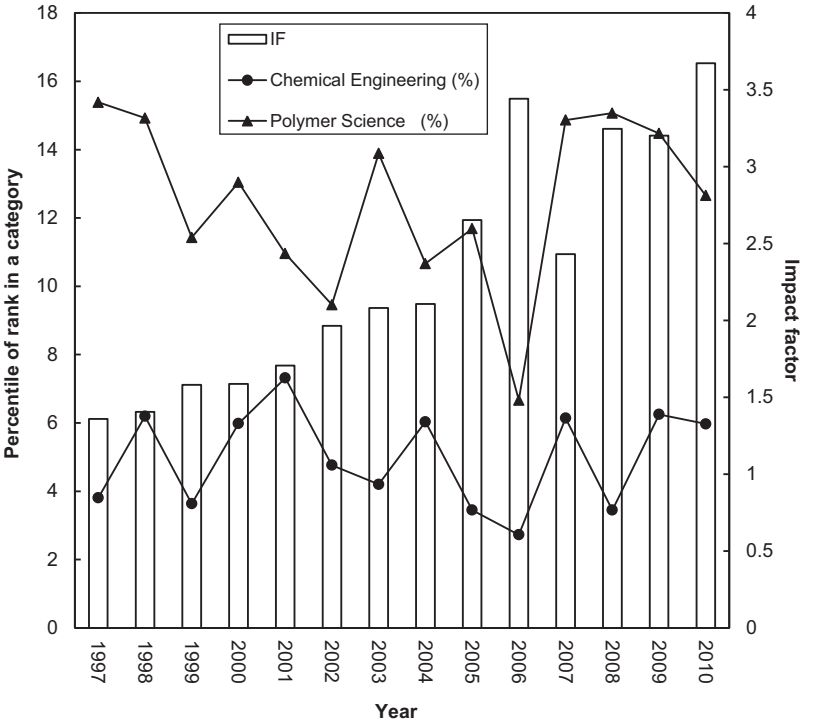

Figure 2.
Rankings of *Journal of Membrane Science* by impact factor in the chemical engineering and polymer science categories from 1997 to 2010

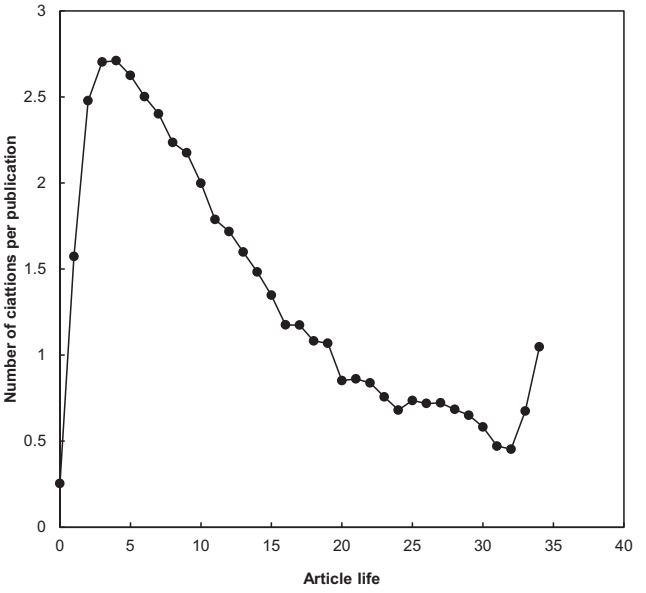

Figure 3.
Trend of number of citations per publication

3.5 Citation life cycles of the most frequently cited articles

Often, the true intellectual milestones may be found in the reference list of the most cited papers, as they influenced a great number of people and helped a great many subsequent advances (Smith *et al.*, 2008). In the early 1970s, the most cited articles were labelled as "classic citations" by Garfield (1974). Table V lists the 34 most cited article published in each year from 1976 to 2009. These articles may be considered "citation classics" emerging from *JMS*. The 29 articles had a TC2010 greater than 100, except the most cited articles of 1978, 2005, 2006, 2007 and 2009. Top articles in recent years may have had lower citations due to the short citation window (Picknett and Davis, 1999). Before 1990, there were no articles with a TC2010 greater than 300, while five articles (TC2010 $>$ 300) were identified after 1990, in 1991, 1995, 2000, 2001 and 2002, respectively.

To determine the performance of articles with great impact recently, citation life cycles of the top eight articles which had the highest C2010 are displayed in Figure 4. The eight articles were all published after 1990, with a TC2010 greater than 100. Among these eight articles, the top five articles are Kreuer (2001), Robeson (1991), Kerres (2001), Wang *et al.* (2002) and Wijmans and Baker (1995), with the highest C2010 the same as the top five articles with the highest TC2010. This performance indicated the strong and durable potential of these articles that were attractive not only after their publication years but also in recent years. In particular, the most cited article (Kreuer, 2001) and the latest top article (Robeson, 2008) rocketed since their publication years. The most cited article was published in 2001 by Kreuer at the Max-Planck-Institut für Festkörperforschung of Germany, with an annual growth rate of 19 citations per year, and is titled, "On the development of proton conducting polymer membranes for hydrogen and methanol fuel cells". The latest top article was published in 1991 by Robeson at the Lehigh University of USA, with the highest annual growth rate of 33 cited times per year, and was titled, "The upper bound revisited". Except for these two, the other six top articles experienced gradual increases, with the annual citations growth rate ranging from four to ten citations per year.

4. Discussion

The average citations of the review document type was four times more than of that of the article document type. It was also shown that reviews received 4.4-fold more citations than articles in another study (Guimaraes and Carlini, 2004). Systematic reviews are cited more often than narrative ones, an indirect endorsement of the hierarchy of evidence (Montori *et al.*, 2003). According to the SCI-Expanded database, the number of articles rose 4-fold from 294,987 in 2000 to 1,059,464 in 2010, while the number of journals climbed from 6,536 in 2000 to 8,005 in 2010. The growth rate of articles during 1976-2010 for *JMS* was much greater than that of the total articles in SCI-Expanded, which indicates the rapid development of *JMS*. According to Figure 1, highly cited articles with no less than 50 citations decreased during the latest eight years (during 2003-2010). This performance could be due to the fact that each paper needs more time to accumulate its total citations (Picknett and Davis, 1999).

G8 countries took an active role in the scientific world. Their performance provides more evidence of the domination by G8 in research, which was also shown

Year	TC2010	Author	Title
1976	164	Aptel *et al.*	Application of pervaporation process to separate azeotropic mixtures
1977	260	Koros *et al.*	Sorption and transport of various gases in polycarbonate
1978	91	Petropoulos and Roussis	Influence of transverse differential swelling stresses on kinetics of sorption of penetrants by polymer membranes
1979	144	Wonders and Paul	Effect of CO_2 exposure history on sorption and transport in polycarbonate
1980	151	Lee	Diffusional release of a solute from a polymeric matrix – approximate analytical solutions
1981	219	Henis and Tripodi	Composite hollow fiber membranes for gas separation – the resistance model approach
1982	164	Berens and Hopfenberg	Diffusion of organic vapors at low concentrations in glassy PVC, polystyrene, andpmma
1983	342	Hsu and Gierke	Ion-transport and clustering in nafionperfluorinated membranes
1984	198	Mulder and Smolders	On the mechanism of separation of ethanol water mixtures by pervaporation. 1. calculations of concentration profiles
1985	152	Wijmans *et al.*	Hydrodynamic resistance of concentration polarization boundary-layers in ultrafiltration
1986	130	O'Brien *et al.*	A new technique for the measurement of multicomponent gas-transport through polymeric films
1987	204	Reuvers *et al.*	Formation of membranes by means of immersion precipitation. 1. a model to describe mass-transfer during immersion precipitation
1988	296	Kim *et al.*	Relationship between gas separation properties and chemical-structure in a series of aromatic polyimides
1989	124	Hellums *et al.*	Fluorinated polycarbonates for gas separation applications
1990	205	Coleman and Koros	Isomeric polyimides based on fluorinated dianhydrides and diamines for gas separation applications
1991	713	Robeson	Correlation of separation factor versus permeability for polymeric membranes
1992	139	Wickramasinghe *et al.*	Mass-transfer in various hollow fiber geometries
1993	243	Nolte *et al.*	Partially sulfonated poly(arylene ether sulfone) – a versatile proton conducting membrane material for modern energy-conversion technologies
1994	200	Jucker and Clark	Adsorption of aquatic humic substances on hydrophobic ultrafiltration membranes
1995	454	Wijmans and Baker	The solution-diffusion model – a review
1996	274	Childress and Elimelech	Effect of solution chemistry on the surface charge of polymeric reverse osmosis and nanofiltration membranes

(*continued*)

Table V.
Most cited articles by year from 1976 to 2009

Year	TC2010	Author	Title
1997	359	Hong and Elimelech	Chemical and physical aspects of natural organic matter (nom) fouling of nanofiltration membranes
1998	183	Singh *et al.*	Membrane characterization by solute transport and atomic force microscopy
1999	213	Pivovar *et al.*	Pervaporation membranes in direct methanol fuel cells
2000	358	Zaidi *et al.*	Proton conducting composite membranes from polyether ether ketone and heteropolyacids for fuel cell applications
2001	941	Kreuer	On the development of proton conducting polymer membranes for hydrogen and methanol fuel cells
2002	458	Wang *et al.*	Direct polymerization of sulfonated poly(arylene ether sulfone) random (statistical) copolymers: candidates for new proton exchange membranes
2003	177	Lee *et al.*	Sludge characteristics and their contribution to microfiltration in submerged membrane bioreactors
2004	260	Xing *et al.*	Synthesis and characterization of sulfonated poly(ether ether ketone) for proton exchange membranes
2005	92	Einsla *et al.*	Sulfonated naphthalene dianhydride based polyimide copolymers for proton-exchange-membrane fuel cells Ii. membrane properties and fuel cell performance
2006	87	Jiang *et al.*	Composite silica/nafion (r) membranes prepared by tetraethylorthosilicate sol-gel reaction and solution casting for direct methanol fuel cells
2007	56	Zeng *et al.*	Re-evaluation of $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_3$-delta perovskite as oxygen semi-permeable membrane
2008	107	Robeson	The upper bound revisited
2009	24	Wang *et al.*	Preparation of alkaline anion exchange membranes based on functional poly(ether-imide) polymers for potential fuel cell applications

Table V.

to have occurred in meteorology and atmospheric science journals (Li *et al.*, 2009) and water resources journals (Wang *et al.*, 2011). The USA made the largest contribution to these kinds of journals, such as *American Journal of Roentgenology* (Chen *et al.*, 2003), *Water Research* (Wang *et al.*, 2010) and water resources journals (Wang *et al.*, 2011). There is some evidence that US authors tend to reference articles from US journals rather than from other countries (Campbell, 1990). China has experienced a sustained and remarkable increase in scientific production (Zhou and Leydesdorff, 2006) and has became the world's second largest producer of scientific publications since 2006 (Zhou and Leydesdorff, 2008). Similarly, in pentachlorophenol research (Huang *et al.*, 2008), China showed a better performance in production than its citations. The Chinese Academy of Sciences is an integrated centre and has over 100 branches in different cities all around China (Fu *et al.*, 2011). It is noticeable that the country of *JMS*'s publisher is The Netherlands, ranked 10th by the total articles, while the University of Twente from The Netherlands ranked second by the total number of articles.

The IF was introduced by Garfield and Sher to aid in selecting additional source journals using recent citations received from other journals (Garfield and Sher, 1963),

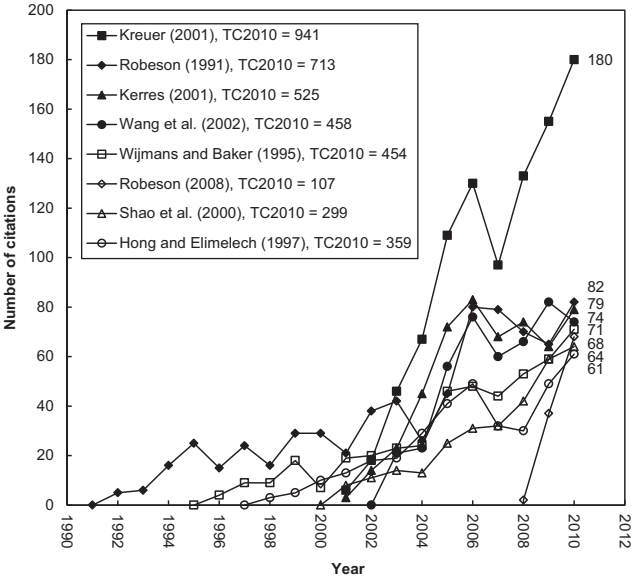

Figure 4.
Citation lives of the top eight articles with the greatest C2010

and has been widely used to rank and evaluate journals (Garfield, 1996; Moed, 2002). The citation pattern of the articles in *JMS* may suggest that IF could be calculated for a longer period after publication to maintain a better citation performance. Therefore, the common indicator IF is not an impartial criterion for all journals, as the PCPP of each journal is different from one another. Different fields show dissimilar citation frequencies for IF (Zetterström, 2002; Hsieh *et al.*, 2004; Chiu and Ho, 2005). The two-year citation window of the IF not only penalizes studies that take longer for citations (Sieck, 2000), but also is considered too short to detect the real impact of publications in "slow" evolving disciplines (Bordons *et al.*, 2002). According to the basic assumption for IF, it is affected by different factors, such as subject area and type of documents (Bordons *et al.*, 2002). It was reported that there are potential mis-use and limitations of this index (Moed, 2002; Hunt, 2011). Therefore, the editors and authors could use the IF as an assisting evaluation indicator, but it is better not to use IF as the sole measure of a journal rank to avoid misleading information. In addition, it should be noted that articles had more time for more citations if they are published earlier. However, this phenomenon was not significant for highly cited articles, which might be due to the difficulty of finding the earlier published papers in the library or on the Internet. Citation life cycles of the highly cited articles differed from each other, which indicated that the progress of accumulating citations needs to be noticed as well. This performance could influence the choice of important references and the evaluation of classic citations for both authors and readers.

5. Conclusion

The application of quantitative bibliometric indicators in the analysis of publication data can provide deep insight to improve the understanding by editors and readers of an academic journal's direction. The article was the dominant document type,

while each review received 4-fold more citations than each article on average, similar to a previous study. The quick increase of production and IF revealed a rapid development of *JMS* during 1976-2010. Interestingly, highly cited articles (TC2010 > 50) centred on the period of 1991-2004, with the highest annual productivity around 1980. The publisher's country for the investigated journal also played an active role as an important contributor. According to IF, the ranking of *JMS* in chemical engineering differs from the polymer science category, which confirmed that IF is affected by subject category. Citation analysis additionally promises to compensate for quality evaluation of the investigated journal on the Web of Science. The year of peak CPP was found to be the fourth year, suggesting a better citation performance of IF calculated by four years. Each journal had its special citations patterns with different year of peak CPP, but the IF of all journals in the Web of Science was calculated by the same method. This study provides new evidence for the misleading role of IF with a 35-year investigation of a science journal. Thus, although the IF has been widely accepted to evaluate journal rankings, it seems that it is not appropriate to use IF as the sole indicator. In addition, the top articles with the most citations were identified in recent years rather than in older years. The citation life cycles could reveal the impact history of the most cited articles, providing important clues for the journal's editors and readers.

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