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A bibliometric analysis of the performance of *Water Research*

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Abstract This paper presents a detailed chronological survey of papers published in the journal titled *Water Research* which started publication since 1967. This current investigation reviews publication patterns between 1967 and 2008. An analysis of the research performance according to publication output, distribution of words in article title, author keywords, and keywords plus. Performances of countries, institutes, and authors, including total, single, collaborative, first author, and corresponding author publications were analyzed. The most-frequently cited articles each year and the articles of the highest impact in 2008 were also reported. Results showed that "activated sludge" was the most frequently used author keyword, followed by "adsorption," and "drinking water." Authors from 114 different countries/territories published in the journal, with the most articles submitted by authors from the USA.

Keywords Scientometrics · SCI · Citation · Author Keywords · Journal

Introduction

Water Research publishes refereed, original research papers in all aspects of the science and technology of water quality and water management worldwide. *Water Research* ranked 1 out of 60 in the subject category of "water resources," 13 out of 163 in "environmental sciences," and 3 out of 38 in "environmental engineering" according to Journal Citation Reports (JCR) with an impact factor of 3.587 in 2008. In early years,

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the term "bibliometrics" was presented in a scientific journal—"Journal of Documentation" (Pritchard 1969, Fairthorne 1969). Pritchard (1969) suggested a better name for the subject "statistical bibliography" to be the application of mathematics and statistical methods to books and other media of communication. In the meanwhile, Fairthorne (1969) paraphrased that bibliometrics is a quantitative treatment of the properties of recorded disburse and behavior appertaining to it. In recent years, bibliometrics has been used as a statistical method to analyze the distribution and characteristics of publications. Scientists in each discipline have too many choices of journals to read and refer; therefore, the evaluation of the performance of each journal was deemed necessary to indicate the impact and contribution of each journal in its respective field (Rice 1983). One common way of conducting bibliometric research is to use the Science Citation Index (SCI) database to trace citations. Numerous journals related to science and engineering categories in SCI have been analyzed by their impact and contribution such as, *Clinical Chemistry*, with the impact factor of 5.579 in the category of medical laboratory technology (Rice 1983); *Inorganica Chimica Acta*, with the impact factor of 1.940 in the category of inorganic and nuclear chemistry (Schubert 1996); *Chemical Engineering Journal*, with the impact factor of 2.813 in the category of chemical engineering (Schubert 1998); *Nature*, with the impact factor of 31.434 in the category of multidisciplinary sciences (Arkhipov 1999); and *Solid State Communications*, with the impact factor of 1.557 in the category of condensed matter physics (Marx and Cardona 2003).

In this study, bibliometric techniques were used to help outline a profile of *Water Research* from its first volume in 1967 to 2008. The main data source of the analysis was derived from the SCI database of the Institute for Scientific Information (ISI, Philadelphia, PA, USA).

Methods

In JCR 2008, 6,620 journals are listed in the SCI, of which, 60 journals were included in the subject of water resources. *Water Research* ranked top one by the impact factor of 3.587. Documents published in *Water Research* from volume 1 to 42 during the period of 1967 and 2008 were analyzed through the parameters of document types, publication output, authorship, publication patterns, distribution of keywords, source countries, and the most-frequently cited articles. In most cases, the analysis covered articles in all issues. However, certain articles published in early years may be lost due to the limited data under the available SCI database. Papers originating from England, Scotland, Northern Ireland, and Wales were re-categorized as being from the UK. Articles from Hong Kong were not included in China.

Contributions of different institutes 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, where the term "single country publication" was assigned if the researchers' addresses were from the same country. The term "internationally collaborative publication" was designated to those articles that were coauthored by researchers from multiple countries. The term "single institute publication" was assigned if the researchers' addresses were from the same institute. The term "inter-institutionally collaborative publication" was assigned if authors were from different institutes.

Results and discussion

A total number of 11,854 documents published in the volumes 1–42 (1967–2008) of *Water Research*, in which the article was the most frequently used document type and comprised 92% of 10,894 documents, followed distantly by notes (2.9%), reviews (1.5%), editorial materials (1.3%), letters (0.57%), meeting abstracts (0.56%), book reviews (0.44%), corrections (0.41%), addition corrections (0.21%), discussions (0.13%), proceedings papers (0.034%), biographical-items (0.017%), abstracts of published items (0.0084%) and items about an individual (0.0084%). As journal articles represented the majority of peer-reviewed document types in this journal, 10,894 articles were used for further analysis in this study. The predominant language for journal articles in *Water Research* was English, followed by French (168; 1.5%) and German (4; 0.037%).

Publication output

From 1967 to 2008, the annual number of articles published in *Water Research* increased about eight-fold, and the number of articles increased from 59 in 1967 to 496 in 2008. The average article length fluctuated from a maximum of 11 pages in 1973 to a minimum of 6.1 pages in 1977, with an overall average length of 8.0 pages. The number of authors also increased from 1967 to 2008. The average number of authors per article ranged from a minimum of 1.8 authors per article in 1970, 1971, and 1972 to a maximum of 4.1 authors per article in 2008 with an overall average of 3.1 authors per article. A similar observation was noted among the number of cited references per article over the same time frame with an overall average of 24 cited references per article.

Country of publication

The analysis of authors' countries in *Water Research* articles was restricted to the period after 1973 due to the limited data under the available database. It was noted that the SCI had a policy of omitting certain addresses (e.g. those preceded by the phrase "on leave from"), but the number of losses from such omissions was statistically negligible (Schubert 1998). All articles (526; 4.8%) published in the period of 1967 and 1972 had no author address information in ISI. Table 1 shows the top 10 countries/territories ranked by the number of articles. Among the 10,368 articles with author address information, international collaborations accounted for 14% of the articles compared to 86% from single countries. One hundred and seventeen countries published articles in *Water Research*. Twenty-nine countries had no single-country articles while 10 countries had no internationally collaborative articles. The USA ranked top one on all indicators, such as total (26%), single country (25%), internationally collaborative (32%), first author (24%), and corresponding author publications (22%). Single-country articles were authored by 88 different countries/territories, most of which, originated from the USA followed by the UK. This result is usual, as the USA was top in most research fields in publications (Schubert 1996, 1998; Marx and Cardona 2003). The USA also had the most frequent partners followed by the UK with 16%. Moreover, G7 (USA, UK, Canada, France, Japan, Germany, and Italy) had high productivity in independent papers (59%), first author publications (57%), and corresponding author publications (55%). In 2008, the USA exhibited its predominance in *Water Research* with 127 articles followed distantly by China (56) and Germany (40). The temporal analysis of the top eight most-productive countries in 2008 was displayed in Fig. 1. During the study period, the total publications of

Table 1 Top 10 most productive countries/territories of articles during 1973–2008

Country/territory	TP	TPR (%)	SPR (%)	CPR (%)	FAR (%)	RPR (%)
USA	2,706	1 (26)	1 (25)	1 (32)	1 (24)	1 (22)
UK	1,065	2 (10)	2 (9.3)	2 (16)	2 (9.2)	2 (8.2)
Canada	792	3 (7.6)	3 (7.2)	4 (11)	3 (6.9)	3 (6.3)
France	678	4 (6.5)	5 (5.7)	3 (12)	4 (5.7)	5 (5.9)
Japan	640	5 (6.2)	4 (5.9)	7 (8.1)	5 (5.6)	4 (6.1)
Australia	437	6 (4.2)	6 (3.8)	12 (6.7)	7 (3.7)	7 (3.8)
Spain	428	7 (4.1)	7 (3.7)	11 (7.0)	6 (3.7)	6 (4.2)
Netherlands	406	8 (3.9)	8 (3.3)	8 (7.9)	8 (3.4)	9 (3.3)
Germany	405	9 (3.9)	9 (2.9)	5 (10)	9 (3.0)	8 (3.3)
China	312	10 (3.0)	12 (2.0)	6 (9.4)	11 (2.2)	11 (2.5)

TP total publications; TPR (%), SPR (%), CPR (%), FAR (%), RPR (%): the rank and percentage of total publications of one country, single country publications, internationally collaborative publications, first author publications, and corresponding author publications in their total publications respectively

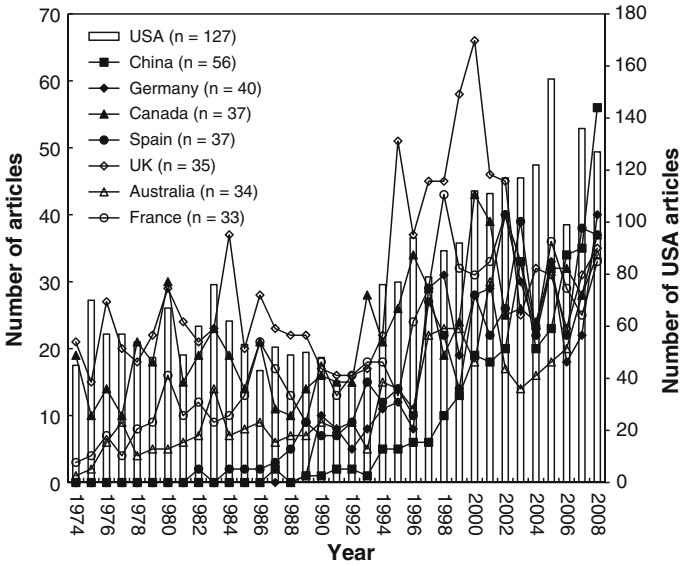

Fig. 1 Publications of the eight most productive countries in 2008

China ranked 10 with 312 articles which were much less than those of the USA, the UK, and Canada. The publications of China grew sharply, while others increased slowly in last 10 years. China had the fastest growing economy in the world. Since 1997, when the National Basic Research Program (also called 973 Program) was approved by the Chinese government (www.973.gov.cn), the publications of China started growing in many fields. In 2008, the China publications in *Water Research* reached the top two and only behind the USA in the world.

Table 2 Top 10 most productive institutes of articles during 1973–2008

Institutes	TP	TPR (%)	SPR (%)	CPR (%)	FAR (%)	RPR (%)
U.S. Environmental Protection Agency, USA	141	1 (1.4)	3 (0.75)	1 (2.2)	3 (0.74)	2 (0.77)
Technical University of Denmark, Denmark	109	2 (1.1)	2 (0.98)	3 (1.2)	2 (0.80)	1 (0.84)
University of Illinois, USA	109	2 (1.1)	6 (0.72)	2 (1.5)	1 (0.81)	4 (0.65)
Technion Israel Institute of Technology, Israel	86	4 (0.83)	1 (1.0)	50 (0.54)	4 (0.72)	4 (0.65)
The University of Queensland, Australia	83	5 (0.80)	5 (0.74)	11 (0.89)	5 (0.68)	3 (0.70)
The University of Tokyo, Japan	76	6 (0.73)	13 (0.51)	7 (1.1)	8 (0.53)	19 (0.42)
Delft University of Technology, Netherlands	74	7 (0.71)	21 (0.44)	4 (1.1)	8 (0.53)	10 (0.49)
National Taiwan University, Taiwan	71	8 (0.68)	23 (0.42)	7 (1.1)	7 (0.56)	6 (0.63)
University of Wisconsin, USA	71	8 (0.68)	3 (0.75)	37 (0.59)	6 (0.57)	13 (0.45)
Commonwealth Scientific and Industrial Research Organization, Australia	67	10 (0.65)	7 (0.65)	31 (0.64)	10 (0.49)	8 (0.52)

TP total publications; TPR (%), SPR (%), CPR (%), FAR (%), RPR (%): the rank and percentage of total publications of one institute, single institute publications, inter-institutionally collaborative publications, first author publications, and corresponding author publications in their total publications respectively

Institute of publication

The contribution of different institutes was estimated by the institute of the affiliation of at least one author of the published papers. The articles (10,368) with institute information were submitted by 4,694 different institutes, in which 2,933 (62%) institutes published only one article in *Water Research*, 635 (14%) published 2 articles, and 297 (6.3%) published three articles. Among the top 10 institutes (Table 2), three of them were derived from the USA, followed by Australia with two institutes; and the others from the Netherlands, Denmark, Taiwan, Israel, and Japan had one institute for each respectively. Leading the way were the U.S. Environmental Protection Agency, the Technical University of Denmark, and the University of Illinois in the USA. Technion Israel Institute of Technology in Israel exhibited its predominance in single institute publications, with the U.S. Environmental Protection Agency (the USA) in inter-institutionally collaborative publications, and University of Illinois (the USA) in first author publications. Moreover, corresponding authors always provide the most-profession and funding for a paper. Seventy-two (0.84%) corresponding author articles were addressed in the Technical University of Denmark in Denmark followed by the U.S. Environmental Protection Agency in the USA, and the University of Queensland in Australia.

Authorship

An analysis of authors' total, first author, and corresponding author publications were undertaken for the articles. Table 3 lists the 10 most productive authors. Of the 10,889 articles with author information, there were 20,100 authors. Dr. M. T. Suidan contributed the most with 40, followed by Dr. W. Gujer (39), Dr. C. P. Huang (38), and 37 for Dr. M. C. M. van Loosdrecht, Dr. G. Lettinga, and Dr. C. P. Gerba, respectively. There were 8,525 articles from 5,443 corresponding authors who were from 2,499 institutes and 88 countries. 3,973 (73%) authors only had one article as a corresponding author. In general, the most-performance and support of profession and funding for a paper are from the first author and the corresponding author. Dr. C. P. Huang published the most first author articles and

Table 3 Top 10 most productive authors of articles during 1973–2008

Authors	TP	TPR (%)	FAR (%)	RPR (%)
Suidan, MT	40	1 (0.37)	277 (0.028)	23 (0.12)
Gujer, W	39	2 (0.36)	138 (0.037)	194 (0.047)
Huang, CP	38	3 (0.35)	7 (0.11)	2 (0.22)
van Loosdrecht, MCM	37	4 (0.34)	N/A	8 (0.16)
Lettinga, G	37	4 (0.34)	628 (0.018)	633 (0.023)
Gerba, CP	37	4 (0.34)	73 (0.046)	123 (0.059)
Lee, DJ	35	7 (0.32)	628 (0.018)	1 (0.32)
von Gunten, U	31	8 (0.28)	1,802 (0.0092)	4 (0.20)
Rittmann, BE	28	9 (0.26)	277 (0.028)	194 (0.047)
Logan, BE	27	10 (0.25)	44 (0.055)	4 (0.20)

TP total publications; TPR (%), FAR (%), RPR (%): the rank and percentage of total publications of one author, first author publications, and corresponding author publications in their total publications respectively

Dr. D. J. Lee ranked top one in the number of corresponding author articles (Table 3). However, Dr. R. Andreozzi published 23 articles in *Water Research*, which included 20 first author articles and ranked top one in first author articles and 17 corresponding author articles (top 4 in corresponding author articles) among 20,100 authors. A bias would appear in authorship analysis because two or more authors may have the same name, or authors used different names in their publications (e.g., names change due to marriage). Therefore it is strongly recommended to create an "international identity number (IIN)" which is offered to an individual person when he/she published the first paper in the ISI listed journals. We believe assigning and tracing IIN will be a better way to record the authorship accurately.

Distribution of words in article title, author keywords, and keyword plus

The title of an article always includes the information which author would most like to express to their readers. We statistically analyzed all the single words in the titles of articles in *Water Research*. Some prepositions such as "of" and "in", were discarded, as they were meaningless for further study. The most used word in titles was "water" which appeared in 1,549 articles, followed by "removal" (1,022), "treatment" (974), "sludge" (674), "wastewater" (665), "effect" (644), "activated" (570), "organic" (563), "effects" (501), and "anaerobic" (487).

The words in titles and author keywords supply reasonable details of the article subjects. A total of 7,198 articles with records of author keywords from 1990 to 2008 in the SCI database were analyzed. There were 16,298 keywords listed by authors, among which, 11,780 (72%) keywords were used only once and 1,990 (12%) keywords were used twice. "Activated sludge" was the most frequently used author keyword (373; 5.2%), followed by "adsorption" (322), "drinking water" (256), "wastewater" (252), and "denitrification" (226). Moreover, after "adsorption" (322) and "sorption" (122) were combined, the adsorption technique was identified to be the most popular research method in *Water Research*.

Keywords plus provided search terms extracted from the titles of papers cited in each new article in ISI (Garfield 1990). The keywords "water," "removal," "waste-water," "degradation," "adsorption," "kinetics," "drinking-water," "bacteria," and "oxidation" were highly visible. "Adsorption," "bacteria," and "toxicity" ranked top thirty among words in title, author keywords, and keywords plus.

The most frequently cited articles

The total citation count was obtained from SCI, and this shows the total number of times that a particular article was cited by the journals listed in the SCI database. The number of citations does not necessarily indicate the quality of a paper, but is a measure of its impact and/or visibility in the field. The total citation count was calculated since the article publication year to 2008. The most-frequently cited articles (>100 times) of each year in the time span of 1967–2008 were selected. The most-frequently cited article was "sorption of hydrophobic pollutants on natural sediments" in 1979 by Dr. S. W. Karickhoff, which has been cited 1,567 times since its publication to 2008. Of the 38 most-frequently cited articles of each year, Dr. H. Bader at the Swiss Federal Institute of Technology in Switzerland and Dr. J. Hoigné at the Federal Institute of Water Resources and Water Pollution Control (EAWAG) in Switzerland contributed to the highest number (4) of articles, followed by Dr. Y. S. Ho (3) at the Taipei Medical University in Taiwan. In addition, Dr. Y. S. and Dr. J. Hoigné exhibited their predominance in first author publications with three most-frequently cited articles respectively and followed by Dr. R. W. Matthews at the CSIRO Division of Fuel Technology in Australia with two most-frequently cited articles. Seven most-frequently cited articles were from Switzerland, compared to Taiwan (5), the USA (4), and Australia (3). There were two articles from Spain, UK, Denmark, France, Germany, Netherlands, and Hong Kong respectively; and one article for Japan, South Africa, Czechoslovakia, Canada, Croatia, and India, respectively. Furthermore, there were two articles which had more than 100 citations in 2008. One was "occurrence of drugs in German sewage treatment plants and rivers" in 1998 by Dr. T. A. Ternes at ESWE-Insitute for Water Research and Water Technology in Germany, which was cited 110 times in 2008 and the other one was "the kinetics of sorption of divalent metal ions onto sphagnum moss peat" in 2000 by Dr. Y. S. Ho and Dr. G. McKay at the Hong Kong University of Science and Technology, which was cited 105 times in 2008. However, a bias would appear in authorship analysis because authors might work for different institutions or countries, which would increase the difficulties in analyzing authorship. Therefore an "international identity number (IIN)" is strongly recommended to create. In this study, more recent institutes were considered for authors.

Conclusions

The results contained considerable information concerning *Water Research*'s evolution with time since its inception in 1967. The bibliometric analysis of *Water Research* shows a high percentage of articles and single country publications. G7 (USA, UK, Canada, France, Japan, Germany, and Italy) published about 60% of total, independent, first author, and corresponding author publications. The U.S. Environmental Protection Agency was the most productive institute. Switzerland produced the most highly cited articles. In addition, results also showed that "adsorption" was the most popular technique and "drinking water" got more and more attention from researchers in *Water Research*.

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