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WATER TREATMENT RESOURCES

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ABSTRACT

This study was designed to evaluate the global scientific output in the ISI subject category of "water resources" for the past 16 years. Data were based on the online version of the Science Citation Index Expanded, Web of Science, from 1993 to 2008. Articles referring to water resources were assessed for many aspects, including distributions of source countries, institutes, words in the title, author keywords, and KeyWords Plus. The h-index was also calculated in terms of the characteristics of publications. Distributions of paper titles, the author's keywords, and KeyWords Plus at different periods were applied to evaluate research trends. The analysis showed that researchers paid most attention to groundwater and water quality parameters. Modeling and adsorption were the most popular techniques in water resources research. In addition, the relationship between the impact factor and h-index was significant for journals in the fi rst group. The impact of the most cited articles each year were also discussed along with the article life information.

I.INTRODUCTION

Three-quarters of the Earth's surface is covered by oceans, which dominate the overall impact on the weather and climate system.

[1]. Water is the most preciousglobal commodity with its myriad uses like drinking, industrial production, irrigation and the production of fish, waterfowl and shellfish.

[2]. These include waterfor freshwater systems that provides many non-extractive or instream benefits like flood control, transportation, recreation, waste processing, hydroelectric power, and habitat for aquatic life

[3]. Some benefits, such as irrigation and hydroelectric power, are achieved only by major changes to the flow regime and flow paths from dams and water diversions.

[4]. Degradation of water resources with time is a social concern. Therefore, researchers have investigated the unbalanced distribution of water resources

[5]. According to a review on history of water resource studies, the earliest research was presented in 1910.

[6], and many investigations were implemented in the following years, for example about central and east African water resources

[7], whereas today, water resources science has become one of the most important areas in the water researchfield. The issue of water resources plays an importantrole in the global environment. Over the years, a great deal of progress has been made in water resource monitoring.

[8], water treatment techniques.

[9] water resource management.

[10] adsorption technology

[11] aerosol

[12], hydrologic sciences

[13]hydrogeology

[14] wetland

[15], solid waste

[16] desalination

[17]. The Science Citation Index Expanded (SCI-Expanded), from the Institute for Scientific Information (ISI) Web of Science databases, is the most important and frequently used source database of choice for a broad review of scientific accomplishment in all fields.

[18] Many bibliometric investigations have been carried out in various subject areas, for example the medical fields of oncology.

[19], radiology, nuclear medicine and medical imaging.

[20], otolaryngology

[21], tropical medicine

[22], virology

[23], and dentistry, oral surgery & medicine

[24] as well as the science and engineering fields ecology

[25], microbiology

[26], psychology

[27], biology

[28], and ocean engineering

[29]. Conventional bibliometric methods often evaluate research trends by the publication outputs of countries [30], research institutes .

II. DATA SOURCES AND METHODOLOGY

The data were collected by analyzing articles and citations from the Thomson Reuters Web of Science database which is based on the online version of SCI expanded. According to Journal Citation Reports (JCR), it indexed 6,426 major journals with citation references across 172 scientific disciplines in 2007. All journals thatpublish articles mostly on water resources, were selected from among 59 journals listed in the category of "water resources" indexed by ISI in 2007. Articles originating from England, Scotland, Northern Ireland, and Wales were reclassified as from the United Kingdom (UK). Papers addressed in Hong Kong were not included in China. The impact factor (IF) of a journal is defined by the JCR, and is derived by dividing the number of current citations to articles published in the two previous years by the total number of articles published in the two previous years. It is a measure of the frequency with which the average article in a journal has been cited in a particular year. The IF is used to evaluate a journal's relative importance, especially when compared to others in the same field [37,58]. The IF of each journal was obtained from the 2008 JCR. Contributions from different institutes and countries were estimated by the affiliation of at least one author to the article. Collaboration type was determined by the addresses of the authors, where the term "single country article" was assigned if the researchers' addresseswere from the same country. The term "internationally collaborative article" was designated to those articles that were coauthored by researchers from more than one country. The term "single institute article" was assigned if the researchers' addresses were from the same institute. The term "inter-institutionally collaborative article" was assigned if authors were from different institutes. All the articles referring to the subject category of water resources during 1993–2008 were assessed from the following aspects document type and language of article, characteristics of article output, distribution of output in journals, article output of source country, source institute, author number per single country or institute article, and analysis of words in the title, author keywords, and KeyWords Plus. Keywords were defined as comma-separated items of one or more words. All keywords, both those reported by authors and those assigned by ISI, as well as words in the title were identified and separated into 4 four-year spans (1993–1996, 1997–2000, 2001–2004,and 2005–2008), then their ranks and frequencies werecalculated, and different words with identical meaning and misspelled keywords were grouped and considered as a single keyword. In addition, the h-index was also calculated as a representative indicator of scientific achievement [47]. It was defined as the number of papers with citation number greater than or equal to h[47]. Hirsch suggests that the h-index has a better predictive power than other measures such as total number of published papers and total number of acquired citations [48]. Studies assessing the efficiency of the h-index have pointed out its convergent validity as a major advantage [49–51]. Moreover, quantity and quality of output are usually assessed by "number of publications" and "total citation counts", respectively [50,51]. Therefore, as a quality measure of publication activity, the h-index of languages, journals, research institutes and countries were calculated to evaluate achievements.

III. RESULTS AND DISCUSSION

3.1. Document type and language of publication.

The distribution of document type identified by ISI was analyzed. From this study, 18 document types were found in the total 96,574 publications during 1993–2008. Journal articles (62,258) were the most-frequently used document type with 64% of the total production, followed by proceedings papers (19,769; 20%), editorial materials (5,743; 5.9%), and reviews (1,806; 1.9%). The others were less significant, including news items (799), letters (660), corrections (569), discussions (513), notes (485), addition corrections (208), biographical items (136), software reviews (38), meeting abstracts (30), items about an individual (25), reprints (21), bibliographies (8), book reviews (6), and database review (1). As journal articles were dominant in the document types and peer-reviewed within this field, they were identified and further analyzed. The emphasis of the following discussion was to determine the pattern of scientific production and research activity trends which consisted of authorship, institutes, countries, and trends in the research subjects addressed. Ninety Eight percent of all these journal articles were published in English (60,793) with an h-index of 151. Compared with other investigations, English was the dominant language [21,43,52], followed by French (913), Spanish (407), German (130), Afrikaans (10), Dutch (2), Rumanian (2), and Danish (1) with h-indexes of 14, 6, 11, 2, 0, 1, and 1 for each respectively. A significant correlation was found between the yearly cumulative number of articles and the year from1993 to 2008 [53,54]. The relationship between the cumulative number of articles published each year (P) and the number of consecutive years (Y) studied from 1993 to 2008 was found to be: P = 2088Y1.144 (r2 = 0.997) until 2002 and P = 9568exp (0.1173Y) (r2 = 1.000) for 2002–2008 (Fig. 1).

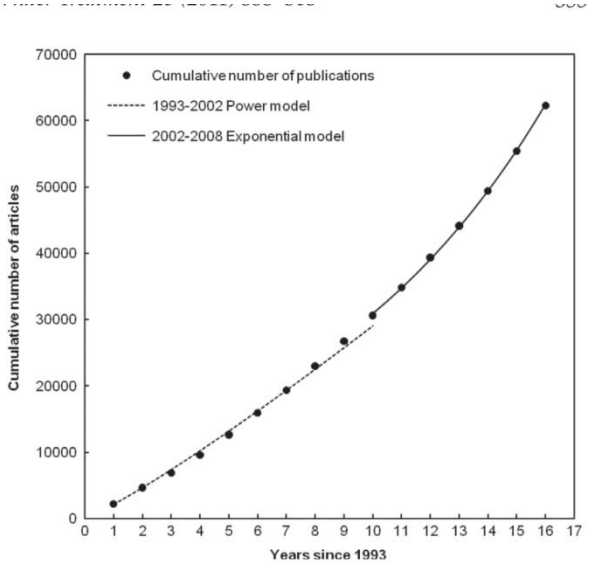

Fig. 1. Cumulative number of articles by year during 1993–2008.

3.2. Distribution of outputs in journals

All journals with their impact factor, impact factor rank, number of articles in 2007, and h-index were statistically analyzed (Table 1). In total, 62,258 articles were published in the 59 searched journals under the category of water resources. Seventeen journals had more than 1,000 published articles referring to water resources research from 1993 to 2008. The h-index provides a new indicator for the research performance and the impact factor is a mature indicator. Water Research published the most articles (6,880; 11%), and had the highest h-index (117). The coefficients of determination between the h-index and the impact factor of journal outputs were calculated (Figs. 2 and 3). Group 1 journals had a coefficient of determination (r2) of 0.81 while group 2 had 0.63.Moreover, Bradford's Law of Scattering [55] was applied. The journals were sorted in descending order in terms of number of articles, and then divided into three "zones".

Zone 1 represents the most productive one-third of the total articles, with 5 (8.5%) of 59 journals.Zone 2 represents the next most productive one-third of total articles, with 14 (24%) of 59 journals, and Zone 3 represents the least productive one-third of total articles with 40 (68%) of 59 journals. The number of journals in the three zones approximately followed Bradford'slaw. To reiterate, the number of journals was approximately 1: n: n2 (1: 2.8: 8). The water resources category contained five Bradford's core journals, Water Research, Water Resources Research, Journal of Hydrology, Water Air and Soil Pollution, and Environmental Geology

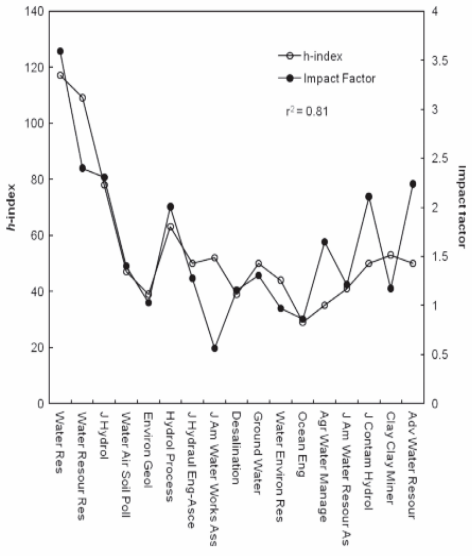

Fig. 2. Relationship between *h*-index and impact factor (Group 1).

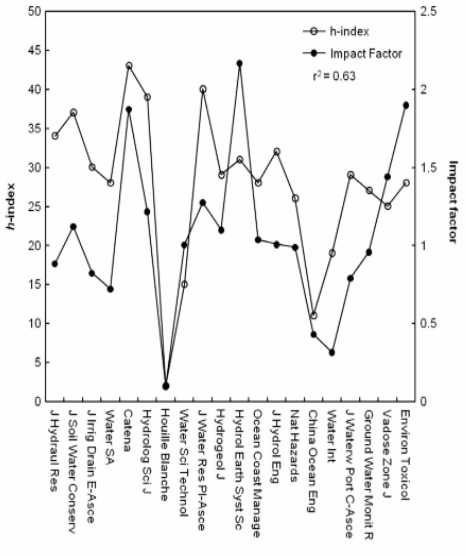

Fig. 3. Relationship between *h*-index and impact factor (Group 2).

and corresponding author articles. Domination in articles from the mainstream countries was not surprising since this pattern occurs in other scientific fields [43]. The USA was predominant in global water resources research and published the most articles (21,851; 36%). The USA was also the most frequent partner accounting for 42% of all the internationally collaborative articles. However, the collaborative articles represented only 23% of the total articles from the USA, which was lower than that of European countries (Table 2). The article impact of the USA was excellent with the highest *h*-index (123) among all the countries, followed by

Table 1
All journals in the category of water resources in SCI-Expanded

Journal title	TA (%)	IF	IFR	TA (2007)	*h*-index
Water Research	6,880 (11)	3.587	1	509	117
Water Resources Research	5,345 (8.6)	2.398	2	505	109
Journal of Hydrology	4,223 (6.8)	2.305	3	404	78
Water Air and Soil Pollution	2,961 (4.8)	1.398	15	249	50
Environmental Geology	2,674 (4.3)	1.026	31	459	26
Hydrological Processes	2,396 (3.8)	2.002	7	415	50
Journal of Hydraulic Engineering-ASCE	1,855 (3.0)	1.272	20	185	30
Journal American Water Works Association	1,678 (2.7)	0.561	51	91	21
Desalination	1,602 (2.6)	1.155	25	747	15
Ground Water	1,522 (2.4)	1.304	18	84	34
Water Environment Research	1,480 (2.4)	0.966	36	153	25
Ocean Engineering	1,444 (2.3)	0.857	41	163	19
Agricultural Water Management	1,386 (2.2)	1.646	12	138	29
Journal of the American Water Resources Association	1,285 (2.1)	1.208	23	117	39
Journal of Contaminant Hydrology	1,253 (2.0)	2.106	6	97	63
Clays and Clay Minerals	1,169 (1.9)	1.171	24	47	2
Advances in Water Resources	1,129 (1.8)	2.235	4	137	47
Journal of Hydraulic Research	991 (1.6)	0.883	40	92	22
Journal of Soil and Water Conservation	984 (1.6)	1.121	28	87	31
Journal of Irrigation and Drainage Engineering-ASCE	981 (1.6)	0.822	42	115	23
Water SA	946 (1.5)	0.721	46	82	20
Catena	907 (1.5)	1.874	11	147	44
Hydrological Sciences Journal-Journal des Sciences Hydrologiques	906 (1.5)	1.216	22	90	43
Houille Blanche-Revue Internationale de L Eau	815 (1.3)	0.096	57	66	7
Water Science and Technology	757 (1.2)	1.005	33	604	19
Journal of Water Resources Planning and Management-ASCE	750 (1.2)	1.275	19	61	37
Hydrogeology Journal	732 (1.2)	1.100	29	115	28
Hydrology and Earth System Sciences	719 (1.2)	2.167	5	104	39
Ocean & Coastal Management	697 (1.1)	1.036	30	72	32
Journal of Hydrologic Engineering	694 (1.1)	1.007	32	134	11
Natural Hazards	684 (1.1)	0.989	35	108	27
China Ocean Engineering	659 (1.1)	0.430	53	46	11
Water International	616 (1.0)	0.315	55	30	8
Journal of Waterway Port Coastal and Ocean Engineering-ASCE	602 (1.0)	0.789	43	32	18
Ground Water Monitoring and Remediation	583 (0.94)	0.957	37	25	28
Vadose Zone Journal	567 (0.91)	1.441	14	122	41
Environmental Toxicology	531 (0.85)	1.899	9	92	39
Aquatic Conservation-Marine and Freshwater Ecosystems	506 (0.81)	1.619	13	107	35
Journal of Water Supply Research and Technology-Aqua	489 (0.79)	0.626	49	57	11
Water Resources Management	488 (0.78)	1.350	16	112	53
Acta Hydrochimica et Hydrobiologica	476 (0.76)	0.907	39	0	19
Environmental Geochemistry and Health	457 (0.73)	1.238	21	61	28
Natural Hazards and Earth System Sciences	448 (0.72)	1.345	17	131	50
Ingenieria Hidraulica en Mexico	409 (0.66)	0.112	56	51	14
River Research and Applications	387 (0.62)	1.959	8	92	52
Water Quality Research Journal of Canada	373 (0.60)	N/A	59	N/A	5
Stochastic Environmental Research and Risk Assessment	367 (0.59)	0.951	38	77	31
Irrigation Science	331 (0.53)	1.891	10	49	50
Irrigation and Drainage	318 (0.51)	0.480	52	45	10
Physics and Chemistry of the Earth	287 (0.46)	1.138	27	186	29
Nordic Hydrology	270 (0.43)	0	58	40	8
International Journal of Water Resources Development	243 (0.39)	0.738	45	42	25
Lake and Reservoir Management	209 (0.34)	0.746	44	0	5
Water and Environment Journal	173 (0.28)	0.648	48	36	24
Clean-Soil Air Water	170 (0.27)	1.145	26	118	40
Environmental Fluid Mechanics	142 (0.23)	1.000	34	42	29
Proceedings of the Institution of Civil Engineers-Water Management	133 (0.21)	0.333	54	38	8
Journal of Hydroinformatics	107 (0.17)	0.681	47	24	17
Proceedings of the Institution of Civil Engineers-Maritime Engineering	72 (0.12)	0.571	50	14	18

TA (%): total number and percentage of articles; IF: impact factor in 2008; IFR: rank in descending order of impact factor; TA (2007): total

Table 2
Top 20 most productive countries/territories of articles during 1993–2008

Countries	Region	TA	TA R (%)	SA R (%)	CA R (%)	FA R (%)	RA R (%)	%C	*h*-index
USA	American	21,851	1 (36)	1 (34)	1 (42)	1 (31)	1 (31)	23	123
UK	European	4,647	2 (7.6)	2 (5.9)	2 (14)	2 (6.1)	2 (6.1)	37	77
Canada	American	4,293	3 (7.0)	3 (5.7)	3 (12)	3 (5.7)	3 (5.6)	34	76
China	Asian	3,209	4 (5.2)	4 (4.0)	5 (10)	4 (4.2)	4 (4.3)	39	47
France	European	3,158	5 (5.1)	6 (3.7)	4 (11)	5 (3.9)	5 (3.9)	42	62
Germany	European	2,847	6 (4.6)	8 (3.3)	6 (10)	7 (3.4)	7 (3.5)	43	66
Australia	Oceania	2,693	7 (4.4)	7 (3.5)	7 (8.2)	6 (3.5)	6 (3.5)	37	66
India	Asian	2,338	8 (3.8)	5 (3.7)	13 (4.1)	8 (3.4)	8 (3.4)	21	49
Italy	European	2,326	9 (3.8)	9 (3.0)	10 (6.9)	9 (3.1)	9 (3.2)	36	59
Spain	European	2,171	10 (3.5)	10 (3.0)	11 (5.8)	10 (3.0)	10 (3.0)	32	57
Japan	Asian	2,138	11 (3.5)	11 (2.5)	9 (7.3)	11 (2.6)	11 (2.7)	41	53
Netherlands	European	1,834	12 (3.0)	14 (1.9)	8 (7.6)	12 (2.2)	12 (2.1)	49	61
Taiwan	Asian	1,282	13 (2.1)	12 (2.1)	24 (2.1)	13 (1.9)	13 (2.0)	20	51
Turkey	European	1,216	14 (2.0)	13 (2.0)	25 (2.0)	14 (1.8)	14 (1.9)	20	42
Switzerland	European	1,142	15 (1.9)	20 (1.0)	12 (5.3)	17 (1.3)	18 (1.3)	56	51
South Korea	Asian	1,127	16 (1.8)	16 (1.3)	14 (3.9)	16 (1.5)	16 (1.5)	41	46
South Africa	African	1,093	17 (1.8)	15 (1.8)	27 (1.7)	15 (1.7)	15 (1.6)	19	29
Sweden	European	1,026	18 (1.7)	17 (1.2)	15 (3.8)	18 (1.3)	17 (1.3)	44	47
Israel	Asian	872	19 (1.4)	19 (1.1)	17 (2.7)	19 (1.1)	19 (1.2)	37	45
Belgium	European	814	20 (1.3)	23 (0.76)	16 (3.7)	22 (1.0)	22 (1.0)	54	41

IV. CONCLUSIONS

In this study on the articles in the category of water resources journals listed in SCI-Expanded, significant points on worldwide research performance from 1993 to 2008 were revealed. The effort provided a systematic structural picture, as well as clues to the impact of research on water resources. Even though English was the dominant language, eight other languages were also used, which indicated global concern about water resources. Apparently more authors, institutes, and countries were engaged in this research over the 16 years. The United States Geological Survey was the pioneer in the field of water resources, with the most independent, inter-institutionally collaborative, first author, and corresponding author articles. Furthermore, the *h*-index (64) of the United Stated Geological Survey was the highest. The G7 along with China, India, Australia, and Spain had a long research history in this field. China showed a rapidly ascending trend in the number of articles during the last 6 years. Not only did they have the absolute ascendancy of articles, but were also the mostfrequent research partners and had higher *h*-in dices. The number of journals published in three zones of articles approximately followed Bradford's law. We calculated the coefficients of determination of the impact factor and the *h*-indices, and found that the journals in the second group had a weaker relationship than that in the first group. In terms of the distributions of words in the paper titles, "river" and "groundwater" were the most concerned "water bodies". In the author keywords analysis, the two most frequently used keywords were "groundwater" and "water quality". The topics, "runoff", "wastewater", "irrigation", and "evapotranspiration" had become new foci. The top four most frequently used KeyWords Plus were "water", "model", "flow", and "transport".

"Management", "waste-water", "runoff", and "variability" were active research areas. In addition, "modelling" and "adsorption" were the most popular techniques. The most frequently cited paper each year was a backstage pioneer in the research field. The article published in *Water Research* by Tern's in 1998 had been cited 630 times up to 2008. But its citation rate decreased in the past two years. Another paper published in 2000 by Ho and McKay still has a great impact on current water resources research. This study provided researchers with a panorama of global water resources research and established further research directions.

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