Research articles and publication trends in environmental sciences from 1998 to 2009

Ming-Huang Wang[1] and Yuh-Shan Ho[1,2]*
[1]*Department of Environmental Sciences, Peking University, The Key Laboratory of Water and Sediment Sciences, Ministry of Education, Beijing 100871, People's Republic of China*
[2]*Trend Research Centre, Asia University, Taichung County 41354, Taiwan*
**To whom correspondences should be addressed*
E-mail: ysho@asia.edu.tw

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Abstract

This study was designed to evaluate global research and publishing trends in the ISI subject category of "environmental science" from 1998 to 2009. Data were based on the online version of the Science Citation Index Expanded, Web of Science. Articles referring to environmental science were evaluated based on document-type distributions. Distributions of words in article titles, author keywords, and KeyWords Plus at different periods were analysed. The results of the word distributions were analyzed for word cluster to evaluate research trends. The analyses showed that water-related topics received the most attention from researchers. An increasing trend was found in wastewater research after 2004. Overall, model, carbon, and adsorption were the three hot research topics in the environmental science category.

Keywords: Research Trends, Environmental Science, Bibliometric, Word Cluster Analysis

1. Introduction

The historical origins of U.S. Environmental Protection Agency's priority pollutants and the development of the "Priority Pollutant Protocol" were reported in 1979 [1]. Numerous studies related to environmental science were implemented in the following years including red and photographic infrared linear combinations for monitoring vegetation [2], sorption of hydrophobic pollutants on natural sediments [3], electromagnetic determination of soil water content [4], macropores and water-flow in soils [5], and three-dimensional stochastic-analysis of macrodispersion in aquifers [6], whereas today, research in the environmental sciences has become a premier area of investigation. Over the years, a great deal of progress has been made in environmental research topics such as aerosol [7,8], pollution of surface waters [9,10], pharmaceutical substances in environment [11-13], estrogenic chemicals [14-16], adsorption [17,18].

The bibliometric method has been widely applied to the analysis of scientific production and research trends. In recent years, many bibliometric investigations have been carried out in environment-related topics, including tsunami [19], multivariate methods [20], pentachlorophenol [21], contingent valuation [22], aerosol [23], biosorption [24], ocean circulation [25], atmospheric simulation [26], volatile organic compounds [27], risk assessment [28], wetland [29], lead in drinking water [30], solid waste [31], desalination [32], and climate change [33]. In 2011, the bibliometric analysis of research articles published in water resources journals was reported [34]. High-impact papers presented in the subject category of water resources in the essential science indicators database of the institute for scientific information [35] and the bibliometric analysis of the performance of *Water Research* were also presented [36]. 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. Bibliometric methods often evaluate research trends by the publication outputs of countries [37,38] and research institutes [39,40]. However, merely depending on the change in the citations or publication counts of countries and organizations cannot completely define developmental trends or the future orientation of the research field. Recently, distribution of words in the article title, author keywords, KeyWords Plus [23] and words in the article abstract [27] used in different periods was applied to evaluate research trends. The KeyWords Plus in the SCI-Expanded database supplies additional search terms extracted from

the titles of articles cited by authors in their bibliographies and footnotes [41].

In this study, we aimed to systematically use the traditional method of bibliometric research and analysis. The distributions of words in the title, author keywords, and KeyWords Plus in different periods were analyzed. In addition, the impacts of the highly cited article were investigated by article life.

2. Materials and Methods

The data were based on the online version of the Science Citation Index Expanded (SCI-Expanded), the Thomson Reuters Web of Science. SCI-Expanded is a multidisciplinary database collected from the Institute for Scientific Information (ISI). According to Journal Citation Reports (JCR), it indexed 7,487 major journals with citation references across 173 scientific disciplines in 2009. All the journals, which publish articles mostly on environmental science, were selected from among 181 journals listed in the category of environmental sciences indexed by ISI in 2009.

The records were downloaded into spreadsheet software, and additional coding was manually performed using Microsoft® Excel [version] to obtain frequently distribution and percentages. An assessment on all the articles referring to the subject category of environmental sciences during 1998-2009 was performed based on the following aspects: document types and languages of articles, characteristics of article outputs, and analysis of words in the article title, author keywords, and KeyWords Plus. All keywords, both those reported by authors and those assigned by ISI, as well as words in the article title were identified and separated into 4-year span (1998-2001, 2002-2005, and 2006-2009), then their ranks and frequencies were calculated.

Table 1. Characteristics of articles published in environmental sciences from 1998 to 2009

Year	TP	AU	AU/TP	PG	PG/TP	NR	NR/TP	NJ	TP/NJ
1998	9,626	31,270	3.2	99,562	10	272,929	28	126	76
1999	10,552	34,995	3.3	112,069	11	301,738	29	126	84
2000	10,850	36,220	3.3	111,625	10	323,756	30	127	85
2001	11,931	40,990	3.4	122,717	10	359,064	30	129	92
2002	12,377	44,243	3.6	129,624	10	382,810	31	132	94
2003	13,841	50,607	3.7	147,558	11	435,883	31	131	106
2004	14,676	55,184	3.8	152,530	10	475,718	32	134	110
2005	16,519	63,618	3.9	169,863	10	544,394	33	140	118
2006	18,726	73,326	3.9	191,446	10	632,355	34	144	130
2007	20,838	83,128	4.0	206,246	9.9	710,900	34	160	130
2008	23,232	93,918	4.0	223,068	9.6	811,817	35	163	143
2009	25,448	105,669	4.2	233,564	9.2	919,666	36	181	141
Total	188,616	713,168		1,899,872		6,171,030		1,693	
Average			3.8		10		33		111

TP, number of articles; AU, number of authors; PG, page count; NR, cited reference count; NJ, number of journals in category of environmental sciences in JCR science edition; AU/TP, the average number of author per article; PG/TP, the average page count per article; NR/TP, the average cited reference count per article; TP/NJ, the average published article per journal

3. Results and Discussions

3.1. Document Type and Language of Publication

The distribution of document type identified by ISI was analyzed. Sixteen document types were found in the total 259,586 publications during 1998-2009. Journal articles (188,616) were the most-frequently used document type with 73% of the total production, followed by proceedings papers (25,374; 9.8%), and editorial materials (10,737; 4.1%). The others were less significant, including reviews (6,635)

news items (5,668), letters (2,692), meeting abstracts (2,684), corrections (1,699), book reviews (662), biographical-items (485), reprints (140), software reviews (58), bibliographies (20), addition corrections (2), and one for each of database review and hardware review. Since journal articles were the dominant types of documents, they were identified and further analyzed. The emphasis of the following discussion was to determine the research activity trends that consisted information of distributions of words in article titles, author keywords, and KeyWords Plus in different periods. Almost one hundred percent of all these journal articles were published in English (187,731; 99.5%), followed by German (777), French (65), Polish (24), Lithuanian (13), Rumanian (4), and Welsh (4).

Table 2. Top 25 most frequent words in article titles during 1998-2009 and 3 four-year periods

Words in title	Total articles	98-09 Rank (%)	98-01 Rank (%)	02-05 Rank (%)	06-09 Rank (%)
water	11,432	1 (6.1)	1 (5.6)	1 (5.8)	1 (6.5)
soil	8,783	2 (4.7)	2 (4.6)	2 (4.8)	2 (4.6)
analysis	6,974	3 (3.7)	3 (3.7)	3 (3.6)	3 (3.8)
assessment	6,386	4 (3.4)	7 (2.8)	5 (3.3)	4 (3.8)
organic	6,303	5 (3.3)	4 (3.4)	4 (3.4)	6 (3.3)
environmental	6,124	6 (3.2)	6 (3.2)	6 (3.2)	5 (3.3)
model	5,810	7 (3.1)	5 (3.3)	7 (3.1)	9 (2.9)
carbon	5,070	8 (2.7)	14 (2.2)	8 (2.6)	8 (3.0)
river	4,940	9 (2.6)	10 (2.4)	9 (2.5)	10 (2.8)
removal	4,761	10 (2.5)	25 (1.9)	16 (2.2)	7 (3.0)
treatment	4,672	11 (2.5)	19 (2.1)	15 (2.2)	11 (2.8)
exposure	4,611	12 (2.4)	9 (2.4)	12 (2.4)	14 (2.5)
evaluation	4,558	13 (2.4)	11 (2.3)	12 (2.4)	15 (2.5)
air	4,412	14 (2.3)	8 (2.4)	11 (2.4)	18 (2.3)
soils	4,266	15 (2.3)	12 (2.3)	10 (2.4)	22 (2.2)
distribution	4,256	16 (2.3)	16 (2.1)	14 (2.2)	16 (2.3)
metal	4,036	17 (2.1)	15 (2.2)	17 (2.1)	23 (2.1)
wastewater	4,011	18 (2.1)	42 (1.6)	29 (1.8)	13 (2.6)
waste	3,913	19 (2.1)	20 (2.0)	29 (1.8)	17 (2.3)
system	3,888	20 (2.1)	22 (1.9)	21 (2.0)	20 (2.2)
concentrations	3,846	21 (2.0)	18 (2.1)	18 (2.0)	26 (2.0)
management	3,700	22 (2.0)	32 (1.8)	33 (1.8)	21 (2.2)
China	3,663	23 (1.9)	176 (0.72)	47 (1.6)	12 (2.8)
species	3,651	24 (1.9)	29 (1.8)	20 (2.0)	28 (2.0)
case	3,605	25 (1.9)	57 (1.3)	27 (1.8)	19 (2.3)

%: percentage of words in article titles in total articles.

3.2. Characteristics of Article Outputs during 1998-2009

The articles published in the environmental sciences field during the time span of 1998 through 2009 are summarized in Table 1. The number of articles increased more than two times, *i.e.*, 9,626 in 1998 to 25,448 in 2009. The number of journals in the category of environmental sciences in JCR science edition also increased from 126 in 1998 to 181 in 2009. The average length of the article has fluctuated from 11 to 9.2. The average number of authors per article also changed from 3.2 to 4.2 and the overall average was 3.8. The cited reference count increased from 28 in 1998 to 36 in 2009 and the overall average was 33.

3.3. Distribution of Words in Article Title Analysis

The title of an article always includes information that the author would most like to express to the readers. It can be used to identify the subjective focus and emphasis specified by the authors. The analysis of article titles has been applied in mapping trends in environmental topics, for example aerosol research [23], atmospheric simulation research [26], adsorption [42], and desalination research [32]. All single words in the title of articles published in environmental science field were statistically analyzed. Commonly appearing prepositions and conjunctions such as "of", "in", "and", "for", "on", "from", "to", and "by" were discarded. Articles including "the", "a", and "an" and common words such as "using", "study", and "effects" were also discarded. The 25 most frequently used words in article titles were grouped in 3 four-year periods (Table 2). The most frequently used words in article titles for all periods were "water", "soil", and "analysis". "China" had extremely high increasing rates in ranking of frequency. "Case", "wastewater", "removal", and "management" in article titles also showed a notable increasing trend. However, the terms "air", "soils", "metal", and "concentrations" in titles showed a decreasing trend during the study period.

Table 3. Top 25 most frequent author keywords used during 1998-2009 and 3 four-year periods

Author keywords	Total articles	98-09 Rank (%)	98-01 Rank (%)	02-05 Rank (%)	06-09 Rank (%)
heavy metals	3,196	1 (2.3)	1 (2.4)	1 (2.1)	1 (2.3)
adsorption	2,159	2 (1.5)	8 (1.1)	2 (1.4)	2 (1.7)
soil	1,891	3 (1.3)	3 (1.5)	3 (1.3)	4 (1.2)
climate change	1,722	4 (1.2)	10 (1.1)	6 (1.0)	3 (1.4)
ozone	1,702	5 (1.2)	2 (1.7)	4 (1.3)	10 (1.0)
sediment	1,477	6 (1.0)	7 (1.1)	10 (0.99)	5 (1.0)
toxicity	1,473	7 (1.0)	4 (1.4)	5 (1.0)	13 (0.91)
cadmium	1,466	8 (1.0)	9 (1.1)	7 (1.0)	6 (1.0)
lead	1,412	9 (1.0)	5 (1.3)	8 (1.0)	16 (0.88)
air pollution	1,395	10 (1.0)	11 (1.1)	11 (0.97)	11 (1.0)
biodegradation	1,349	11 (1.0)	12 (1.0)	14 (0.90)	12 (0.94)
mercury	1,347	12 (0.95)	6 (1.1)	13 (0.90)	14 (0.91)
water quality	1,321	13 (0.93)	20 (0.86)	15 (0.85)	7 (1.0)
groundwater	1,305	14 (0.92)	13 (1.0)	8 (1.0)	17 (0.82)
kinetics	1,250	15 (0.88)	24 (0.76)	20 (0.77)	8 (1.0)
copper	1,234	16 (0.87)	13 (1.0)	12 (0.91)	20 (0.78)
arsenic	1,162	17 (0.82)	50 (0.50)	24 (0.75)	9 (1.0)
wastewater	1,160	18 (0.82)	27 (0.69)	23 (0.76)	15 (0.90)
metals	1,141	19 (0.80)	19 (0.86)	19 (0.80)	19 (0.78)
risk assessment	1,109	20 (0.78)	21 (0.83)	17 (0.81)	22 (0.75)
pollution	1,095	21 (0.77)	17 (0.91)	22 (0.76)	23 (0.72)
fish	1,093	22 (0.77)	16 (0.91)	21 (0.77)	25 (0.72)
conservation	1,073	23 (0.76)	15 (1.0)	16 (0.83)	32 (0.61)
remote sensing	984	24 (0.69)	87 (0.34)	26 (0.71)	18 (0.82)
biodiversity	968	25 (0.68)	25 (0.70)	25 (0.73)	29 (0.64)

%: percentage of author keywords in total articles.

3.4. Distribution of Author Keyword Analysis

Author keyword analyses could offer insight on research trends, which are concerned by researchers. In recent years, bibliometric methods concerning author keyword analysis are available [19]. Using results of distribution of author keywords in different time periods as

one metric for evaluating research trends was reported in research trends of aerosol [23], atmospheric simulation [26], volatile organic compounds [27], and desalination [32]. Examination of author keywords revealed that 212,443 keywords were used. Among them, 151,211 (71%) appeared only once, and 25,065 (12%) keywords appeared twice. The large number of once-only author keywords probably indicated a lack of continuity in research and a wide disparity in research focuses [43]. Similar results were also reported in several research topics, for example aerosol [23], lead in drinking water [30], and adsorption dye from wastewaters [42]. Furthermore, these keywords might not be standard or widely accepted by researchers [44]. Table 3 showed distributions of the top 25 most active author keywords. The most frequently used keyword(s) for all periods was "heavy metals" followed by "adsorption", "soil", "climate change", and "ozone". Author keywords "remote sensing", "arsenic", "kinetics", "water quality", and "wastewater" had high increasing rates in ranking of frequency, which might be identified as current research hotspots in environmental science field. "Climate change" and "adsorption" also had an increasing rate in ranking of frequency. The ranking of a few keywords did not fluctuate distinctly, showing the related research was basically steady in the past 12 years. However using keywords such as "conservation", "lead", "toxicity", "fish", "ozone", and "mercury" decreased.

Table 4. Top 25 frequent KeyWords Plus used during 1998-2009 and 3 four-year periods

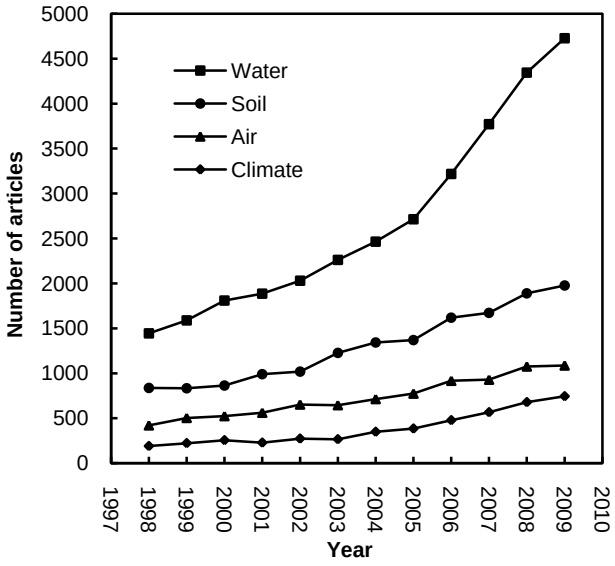
KeyWords Plus	Total articles	98-09 R (%)	98-01 R (%)	02-05 R (%)	06-09 R (%)
water	9,998	1 (6.0)	1 (6.4)	1 (6.0)	1 (5.8)
model	6,179	2 (3.7)	2 (3.7)	2 (3.8)	3 (3.7)
soil	4,902	3 (2.9)	3 (3.1)	4 (3.0)	9 (2.8)
degradation	4,844	4 (2.9)	9 (2.4)	6 (2.7)	4 (3.3)
exposure	4,798	5 (2.9)	10 (2.3)	3 (3.1)	7 (3.0)
adsorption	4,734	6 (2.8)	8 (2.5)	9 (2.6)	6 (3.1)
removal	4,728	7 (2.8)	21 (1.6)	12 (2.4)	2 (3.7)
heavy-metals	4,681	8 (2.8)	12 (2.1)	8 (2.6)	5 (3.2)
toxicity	4,435	9 (2.7)	4 (2.8)	5 (2.7)	10 (2.6)
growth	4,291	10 (2.6)	7 (2.6)	7 (2.7)	11 (2.5)
transport	4,025	11 (2.4)	5 (2.6)	10 (2.5)	13 (2.3)
sediments	3,942	12 (2.4)	6 (2.6)	11 (2.4)	14 (2.2)
waste-water	3,609	13 (2.2)	57 (1.0)	22 (1.8)	8 (2.9)
polycyclic aromatic-hydrocarbons	3,440	14 (2.1)	19 (1.7)	13 (2.2)	18 (2.1)
kinetics	3,404	15 (2.0)	17 (1.8)	15 (2.1)	17 (2.2)
management	3,390	16 (2.0)	37 (1.3)	19 (1.8)	12 (2.5)
oxidation	3,385	17 (2.0)	15 (1.8)	16 (2.0)	16 (2.2)
cadmium	3,375	18 (2.0)	11 (2.3)	14 (2.1)	20 (1.9)
sorption	3,336	19 (2.0)	15 (1.8)	18 (1.9)	15 (2.2)
pollution	3,089	20 (1.9)	25 (1.6)	17 (1.9)	19 (2.0)
soils	3,002	21 (1.8)	13 (1.9)	21 (1.8)	26 (1.8)
accumulation	2,976	22 (1.8)	14 (1.8)	20 (1.8)	25 (1.8)
temperature	2,841	23 (1.7)	23 (1.6)	25 (1.7)	23 (1.8)
dynamics	2,841	23 (1.7)	22 (1.6)	23 (1.8)	28 (1.7)
vegetation	2,807	25 (1.7)	20 (1.6)	24 (1.7)	31 (1.7)

R (%): rank and percentage of KeyWords Plus in total articles.

3.5. Distribution of KeyWords Plus Analysis

KeyWords Plus, which supplied additional search terms, was extracted from the titles of papers cited by authors in their bibliographies and footnotes in the ISI database [41]. The KeyWords Plus substantially augmented title-word and author-keyword indexing. Distribution of KeyWords Plus in different periods was applied to be information to evaluate research trends in recent years [23,26,27]. 166,556 articles in all were found to include 117,976 KeyWords Plus information. Table 4 showed the 25 most frequently used KeyWords Plus with their rankings and percentages. The KeyWords Plus "water" and "model" ranked top of the list. "Waste-water", "management", and "removal" had become a new focus, the frequency of which ranking from 57th, 37th, and 21st in 1998-2001 to 8th, 12th, and 2nd in 2006-2009 respectively. By contrast, the KeyWords Plus "soils", "accumulation", and "vegetation" decreased from 13th, 14th, and 20th in 1998-2001 to 26th, 25th, and 31st in 2006-2009.

Figure 1. Comparison of the trends of water, soil, air, and climate.

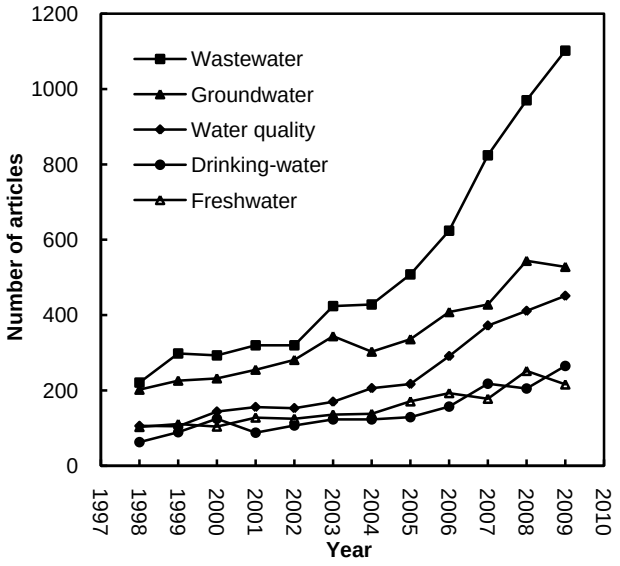


3.6. Research Hotspot Analysis

The technique of statistical analysis of keywords might be aimed at discovering directions of research, and prove important for monitoring development of science. 188,616 articles with records of title in the environmental science field from 1998 to 2009 were analyzed. On the Web of Science, there were 141,985 (75%) articles with author keywords and 166,556 (88%) articles with KeyWords Plus information. A bias appeared in analysis distribution of words in article titles, author keywords, and KeyWords Plus. Single word could be considered in words in article titles but not included phrases. Only seventy-five percent of articles had author keywords. Twenty-three journals had no author keywords, for example *Environmental Science & Technology*, *Journal of Environmental Quality*, *Journal of the Air & Waste Management Association*, and *Aerosol Science and Technology*. However, author keywords included single words, abbreviations, and phrases. KeyWords Plus could be added to articles published in journals without author keywords. KeyWords Plus might not be found in articles title, author keywords, and article abstract. It is clear that there are disadvantage in analysis of words in article title, author keywords, and KeyWords Plus. "Word cluster analysis" was applied to improve the bias. It has been successfully used to analyze the research hotspot in the field of risk assessment [28]. The results of the distribution of the three kinds of keywords could be information of evaluating research trends. Words in the article front page, including article title, abstract, and author keywords, were considered. Publication trends of articles related to four environmental typical topics such as water, soil, air, and climate were showed in Fig. 1. Each topic was supported by a single word or word cluster. For example, water was supported by water, wastewater, wastewaters, waste water, waste waters, groundwater, ground water, ground waters, drinking water, drinking waters, stormwater, rainwater, seawater, freshwater quality, stormwater, and rainwater. Soil supporting words was composed of soil and soils. Air and airborne comprising the supporting word cluster of air. Climate included climate change, climate variability, paleoclimate, climate policy, global climate change, microclimate, and climate warming. An obvious rise can be seen in the number of articles related to water, soil, air, and climate research in environmental science field (Fig. 1). The topics mentioned above might be reflected by some highly cited articles. Topic related to water had the highest growth pace especially after 2005. "Pharmaceuticals, hormones, and other organic wastewater contaminants in US streams, 1999-2000: a national reconnaissance" [13] was published in *Environmental Science & Technology* was the

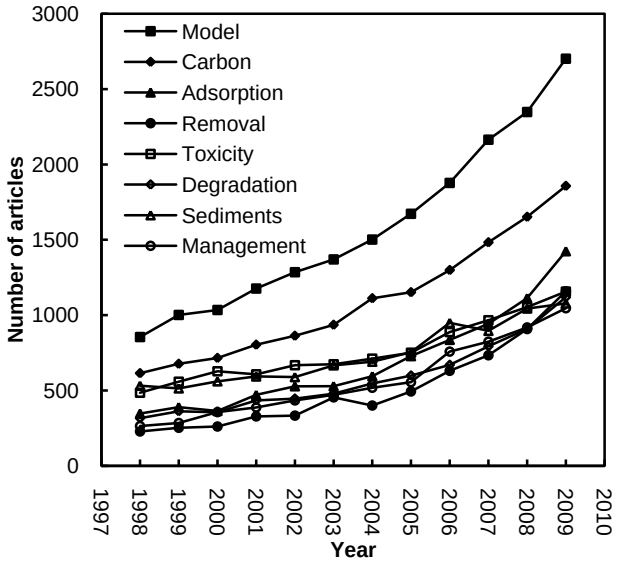
most frequently cited article. It has been cited 1816 time since its publication to 2010. In this study, the U.S. Geological Survey used five newly developed analytical methods to measure concentrations of 95 organic wastewater contaminants (OWCs) in water samples from a network of 139 streams across 30 states during 1999 and 2000. However, some arguments related these organic compounds and the analytical methods were reported after the paper was published [45-47]. Another high impact paper was "nonpoint pollution of surface waters with phosphorus and nitrogen" [9] was published in *Ecological Applications* had been cited 1020 times since its publication to 2010. Article life showed these two high impact water related papers are still highly cited in 2010.

Figure 2. Comparison of the trends of water related topics.



Wastewater, water quality, groundwater, freshwater, drinking-water, and seawater were found to be the most popular research topics which are related to water. Wastewater was supported by wastewater, waste-water, wastewaters, waste-waters, waste water, and waste waters. Water quality was supported by water quality, water-quality, groundwater quality, stormwater quality, rainwater quality, seawater quality, wastewater quality, freshwater quality, stormwater quality, and rainwater quality. Groundwater was supported by groundwater, ground-water, ground water, groundwaters, and ground waters. Freshwater supporting words were composed of freshwater, fresh-water, fresh-waters, freshwaters, fresh water, and fresh waters. Drinking-water included drinking water, drinking waters, drinkable water, drinking river water, drinking water, and drinking safe water. Seawater, sea-water, sea water, and seawaters comprised the supporting word cluster of seawater. Figure 2 shows that publications related to wastewater had a sharper increasing after 2004. Latter water quality publications had also increased. Highly cited articles including "pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000: a national reconnaissance" [13]; "single- and multi-component adsorption of cadmium and zinc using activated carbon derived from bagasse: an agricultural waste" [48]; "ozonation: a tool for removal of pharmaceuticals, contrast media and musk fragrances from wastewater" [49]; "behavior of pharmaceuticals, cosmetics and hormones in a sewage treatment plant" [50]; and "production of electricity during wastewater treatment using a single chamber microbial fuel cell" [51] before 2005.

Figure 3. Comparison of the trends of hot topics in environmental science.



Research trends of hot research topics which included more than 100 articles in 2009 such as model, carbon, adsorption, removal, toxicity, degradation, sediments, and management in environmental science was showed in Fig. 3. Model was the most popular research topic that is keeping increasing and would be the hot topic in the future. The most impact articles to model were "global response of terrestrial ecosystem structure and function to CO_2 and climate change: results from six dynamic global vegetation models" [52] and "evaluating the use

of 'goodness-of-fit' measures in hydrologic and hydroclimatic model validation" [53]. It has been reported that "parameterization" was the most popular research method in atmospheric simulations [26]. Furthermore adsorption had a higher increase rate. Adsorption was also found to be the one of the most frequently investigated topics in the field of water resources [34] and the journal of *Water Research* [36]. The most cited article was "the kinetics of sorption of divalent metal ions onto sphagnum moss peat" [18]. This article was also the most cited article in water resources in the essential science indicators database [35] and the most impact article in the water resources field in 2008 [34]. Another highly cited article related to adsorption was "arsenite and arsenate adsorption on ferrihydrite: kinetics, equilibrium, and adsorption envelopes" [17]. The effect of toxicity, biomarkers of arsenic toxicity and the mechanism of arsenic toxicity on plants and animals and sources of remediation was reported [54].

4. Conclusions

In this study dealing with the publications in the journals listed in the subject of environmental science from 1998 to 2009. Sixteen document types were found in the total 259,586 publications. Seven languages were used in 187,731 articles. In terms of the distributions of words in the article titles, "water", "soil", and "analysis" were the most concerned. In the author keywords analysis, the most frequently used keywords were "heavy metals", "adsorption", "soil", "climate change", and "ozone". The top two most frequently used KeyWords Plus were "water" and "model". The results of word cluster analysis showed that water, soil, air, and climate research were mainly focus in the field of environmental science. Wastewater, water quality, groundwater, freshwater, drinking-water, and seawater were the most popular topics in water research. Model, carbon, adsorption, removal, toxicity, degradation, sediments, and management were the hot research in environmental science.

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